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Investigation and Influence of MWCNTs/Graphene on the Mechanical Properties of Bi-Directionale-Glass/Epoxy Composite

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ABSTRACT: E Composites play a vital role in aerospace, land transportation and consumer goods due to their high specific strength and stiffness, leading to reduction in the mass of moving objects. Glass epoxy composites are an unique materials for some of the important applications such as pressure vessels of commercial applications, Storage of chemicals, sewage treatment plants, chemical industrial applications. Initially for manufacturing a laminate with appropriate finishing and maintaining uniform thickness a **Match-Die-Mold** is designed and fabricated. In the present investigation, I have taken three different resin matrix systems in conjunction with E-Glass bidirectional fabric. The epoxy LY556 (resin system - 1), The epoxy LY 556 with 5% reactive diluents (resin system - 2) & Epofine 1555 (modified epoxy resin with high elongation (resin system - 3).

The basic idea to choose a compatible resin system with E-Glass bidirectional fabric is that the best combinations of mechanical properties are achieved. The mechanical properties are determined by carrying out tests on specimens in tension and flexure in accordance with the test procedure laid down in ASTM-D specifications D-3039 and D-790 \pm 45⁰ specimens has prepared in accordance with D-3518 to study the in-plane shear properties. Inter laminar shear strength will be determined by conducting short-beam shear test with span to thickness ratio less than 4 in accordance with D-2544. Finally after obtaining the tested results, those values are checked by using **ANSYS** software package.

KEYWORDS: E-Glass, ASTM-D, Epofine, ANSYS & EPOXY

I.INTRODUCTION

The future of the modern civilization is depend on the advances in technology and process ability of new materials. Whenever we look backward the Ancient civilization names depict the materials at that time. During the Stone Age (10,000 BC to 3,000 BC), people used only the materials found around them, such as stone, wood, and bone. These materials have been converted into weapons for their basic needs. It is very clear from the history that the development of materials is the prime factor for the modern civilization. Over the years, technological requirements give raised to the advances in materials. At the same situation it's not possible to reach the required properties using a single material. Because of this, the utilisation of composite materials has evolved. It is possible to bring out the best performance of individual constituents from any composite material. Based on predictions, it's assumed to that the demand of composites will increase steadily. Nature has been making composites for millions of years. So the history of composite materials is perhaps as old as that of life on earth. Most of the plant parts have embedded fiber structures for better mechanical properties. Composites can be broadly classified into natural composites and synthetic composites. Some examples of natural composites are wood, bone, etc. The synthetic composites are examples for manmade composites. In synthetic composites, there is sufficient flexibility of selecting a suitable reinforcement and a matrix

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from the wide variety of reinforcements and matrices so that composites with the desired properties can be made. Based on the reinforcement phase, the composites can be classified as fiber-reinforced composites (FRCs) and particulate composites (Figure 1.1). The FRCs can be fabricated as single layer or as multilayer composites. When the layers in a multilayered composite are made with the same type of fiber reinforcement, then it is called a “laminar.” If two or more types of fiber reinforcements are used in different layers, then it is a hybrid composite. In single layer composite, only one layer is present. Long or short fibers are used as reinforcements in single-layer composites. Better load transfer is possible with the fiber reinforcements and hence high mechanical properties are realized. However, the properties are not same in all the directions. Usually, the mechanical properties are high along the fiber direction. Isotropic composites can be easily made with short fibers. During processing, the fibers may align in a particular direction in some of the processing methods and then the composites become anisotropic. However, the composites are isotropic in most of the cases when the short fibers are used as the reinforcement.

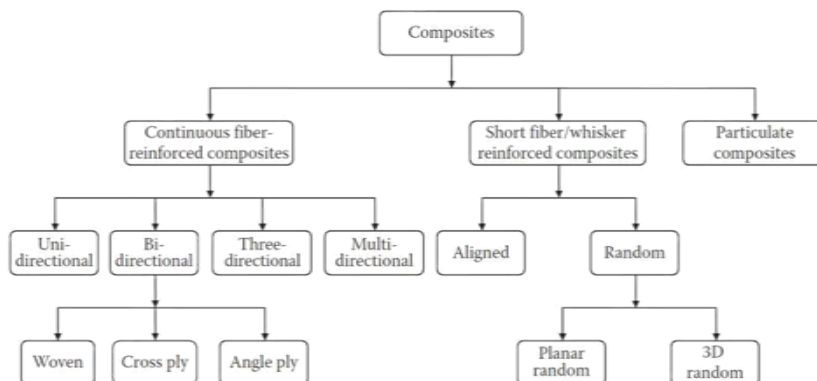


Fig 1.1: Classification of composites based on dispersed phase

A composite material is formed by reinforcing plastics with fibers. To develop a good understanding of composite behaviour, one should have a good knowledge of the roles of fibers and matrix materials in a composite. The important functions of fibers and matrix materials are discussed below. The various functions of the fibers in a composite material are: 1)It has to carry the load ,2)It has to provide various properties like stiffness, strength, thermal stability 3)It has to provide electrical conductivity or insulation, depending on the type of fiber used. 4)A matrix material is intended to do several functions in a composite, most of which are important for the satisfactory performance of the structure. 4)Fibers in and of themselves are of little use without the matrix material or binder. The important functions of a matrix material include the following,5)To fibers together and transfers the load to the fibers. 6)Isolation of fibers to be act as an individual unit while failure.7)To provide fine surface finish.8)To protect fibers. 9)Based on the selected matrix material, performance characteristics such as elongation atbreak, impact strength, etc. are also influenced. 10) All the failure modes are dominated by the matrix material used and its functionality, compatibility with the fiber sizing/coating.

Because of the tailor-ability of composite materials, these are used for all applications in which high performance and light weight are needed. The several advantages of composite materials over commercial materials are given below. 1)Provide part integration capabilities. 2)In service monitoring of structures through which we can monitor the fatigue damage through embedded sensors.3)Good corrosion resistance. 4)Good fatigue strength (approximately 75%). 5)High specific stiffness. 6)The design flexibility will be increased through these materials. 7)Required part dimensions can be produced within minor deviations. 8)Any contours, which cannot be produced with conventional materials, can be made through these materials with increased reliability and less production time. 9)They offer good impact properties.

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10) Good Noise, vibration, and harshness (NVH) characteristics. 11) Through the utilization of selected design and manufacturing techniques, composite parts of cost-effective can be manufactured.

Even though composite materials provide many benefits, they suffer in the following ways: 1) The materials cost for composite materials is very high compared to that of steel and aluminium. It is almost 5 to 20 times more than aluminium and steel on a weight basis. 2) In the past, composite materials have been used for the fabrication of large structures at low volume (one to three parts per day). Because of the lack in high volume production limitations, the use of composite materials is limited. For the sake of higher productions, various known manufacturing techniques like, pultrusion, resin transfer moulding (RTM), filament winding etc are automated. Automotive parts require the production of 100 to 20,000 parts per day. For example, Corvette volume is 100 vehicles per day, and Ford-Taurus volume is 2000 vehicles per day. 3) Designing parts with composites has lack of database. 4) The temperature resistance of composite parts mainly dominated by the temperature resistance of the matrix materials. Because a large proportion of composites use polymer-based. 5) Matrices, temperature resistance is limited by the plastics' properties. 6) Solvent resistance, chemical resistance, and environmental stress cracking of composites depend on the properties of polymers. Some polymers have low resistance to solvents and environmental stress cracking. 7) The moisture absorption characteristics of composites adversely affect the properties and dimensional stability.

Commercial and industrial applications of fiber reinforced composites are diverse and varied. The main application areas may be broadly classified as follows: **Marine field:** The steering wheel, wind transducer shown in Fig1.5 is the components of boats made of fiber. **Sporting goods:** The Accelerator is the one piece, 100% carbon-fiber paddle with ergonomic fit handle and an oval shaft. Weighing less than 420g, with a full length foam core. The Sport Plate is made from a fiber reinforced thermo composite material that's strong and abrasion resistant. **Aircraft and Space:** The B787 Dream liner shown in Fig1.3 has an amazing level of composite construction. Most of the aircraft, approximately 50% is of composite structures. It is the first commercial airliner to have the fuselage and wings made entirely out of carbon fiber instead of aluminium. **Automotive:** Today most of the racing cars chassis, which includes the suspension, wings and engine cover, are built with carbon fiber. One such type of racing car.

II. LITERATURE SURVEY

Polymer matrix composites are predominantly used for the aerospace industry, but the decreasing price of carbon Fibers is providing a way to various commercial and industrial applications. Rim Ben Toumi (1): After observing acoustic emission and microscopic examinations it was found that the failure of composite in fatigue loading was of the same type which has observed in static loading. In this approach semi empirical fatigue model was used to predict the life of the composite including stress ratios, maximum stresses and frequencies. The predictions were matching with the experimental values satisfactorily. Sivasarayanan.S (2): In this experimentation synthesized Epoxy / clay nano composites are tested and results are compared with various weight combinations of composite materials. It was found that, after adding nano clay particles, the impact strength of the epoxy composite was increased. They concluded that, 5% of the weight fractions of nano particles will result in a composite with good impact characteristics. If the weight fractions are more than 5% then it will become brittle, and the preparation of composite will be very difficult. Amal A.M. Badawy(3): In this experimentation, the impact characteristics of Glass Fiber Reinforced Polymers with different layup sequences like uni-directional, bi-directional, cross plied and combinational ply sequences was carried out using izod impact test. At the same time for each combination the effect of temperature on the failure mode of the composite in that particular type of test was studied. Because of the exposure to temperature the failure mode of the specimen has changed from fiber pullout to fiber breakage. Milan Žmindák(4): In this paper computational modeling techniques like Method of Continuous Source Functions (MCSF) and Trefftz Radial Basis Functions (TRBF) for glass fiber reinforced composites were investigated with broad advantages. According to the obtained results, the length of the fiber is much more greater than critical length. we can also find optimal aspect ratio of fibers can be calculated for the required application point of view or parts The MCFS can simulate the interactions of matrix to fiber and fiber to fiber to keep the gradients for the sake of correct estimation of interactions. A. Tasdemirci (5): In this study the effect of strain rate on the compressive strength and elastic modulus of E-Glass Polyester composites were observed in three mutual perpendicular directions of the fiber axis or reference axis. Whenever the strain rate increased, an increment in strength and modulus was observed. The sensitivity of elastic modulus with high strain rate was found in transverse direction. To justify the experiment, a numerical model was developed to predict failures.

III. PROBLEM STATEMENT & METHODOLOGY

1) E-Glass 13mil bi-directional fabric. 2) Epoxy Resins 3) Epoxy LY556 (Resin System 1) 4) Epoxy LY556 with 5 % reactive diluent (Resin System 2). 5) Epofine 1555 (modified epoxy resin with high elongation, (Resin System 3)) 6). Hardener (Aradur HT5200).

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Materials Used to Prepare A Composite Laminate:

1. E-Glass 13mil bi-directional fabric
2. Epoxy Resin
3. Hardener

E-Glass Fiber: Glass fiber is a material which is formed using fine glass fibers. In history, glassmakers have experimented so much about glass fibers, but mass manufacturing of glass fibers has come to true through automation of the process and proper tooling techniques only. Glass fibers have satisfactory mechanical properties to other fibers such as carbon and polymers. Because of its less brittleness and satisfactory strength when compared with carbon, it is widely used in variety of applications.

Epoxy resin is formed when an epoxide is reacted with polyamine hardener. It contains monomer chains with an epoxide group at each end. All the commercially available epoxy resins are prepared using epichlorohydrin and bisphenol A. In all thermosetting type resins, epoxies are unique because of the following reasons. Low pressure requirements during fabrication. Low shrinkage of final product. Ease of curing methodologies with different types of hardeners. Availability with different ranging viscosities.

The hardener used in Epoxy is polyamine which is having two or more primary amino groups $-NH_2$. This class of compounds includes several synthetic substances that are important feed stocks for the chemical industry, such as ethylene diamine $H_2N-CH_2-CH_2-NH_2$, 1,3-diaminopropane $H_2N-(CH_2)_3-NH_2$, and hex methylenediamine $H_2N-(CH_2)_6-NH_2$. The amine groups react with the epoxide groups to form a covalent bond. For the sake of heavily cross linking, each NH group can react with an epoxide group.

A single layer of a laminated composite material is generally referred to as a ply or laminate. It usually contains a single layer of reinforcement, unidirectional or multidirectional. A single lamina is generally too thin to be directly used in any engineering application. Several lamina are bonded together to form a structure termed as laminate. Properties and orientation of the lamina in a laminate are chosen to meet the laminate design requirements. Properties of a laminate may be predicted by knowing the properties of its constituent lamina. In this experimental work the following types of laminates were made with different orientations: 1) $0^\circ/0^\circ$ - (all plies are in 0° direction). 2. $\pm 45^\circ$.

The fabric is laid on work bench covered with polythene sheet.



Fig3.1: Glass fabric



Fig3.2: Marking Fabric

Marking is taken by using 0° and $\pm 45^\circ$ with mould dimensions 390mmx340mm respectively. Resin is weighed as per specifications of fabric that is 100 gm resin, pigmented (5%) for coloured surface typically white is chosen and hardener is added in the ratio of (1/3rd i.e.). Epoxy is stirred well. Bonding agent (epoxy resin) is applied to create bonding between layers. This is usually accomplished by calculating rollers or brushes for forcing resin into the fabrics. The surface of the mould is cleaned with 0-grade Emery paper, the clearance holes are cleaned with

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jewellery files, also cleaned with acetone and a release agent (wax pol) is applied. If the surface is not clean, then the release agent will not function properly.

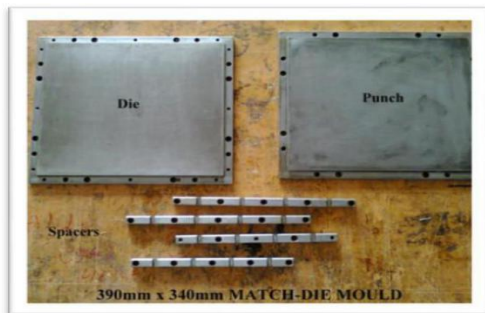


Fig 3.3: Match-Die-Mould



Fig 3.4: Cleaning the Mould

An optional sacrificial layer (Surface mat) is laid up on the mould surface. This layer is usually a fiber glass fabric made with the same resin system as the composite laminate. The sacrificial layer protects the laminate from surface abrasion and surface irregularities during manu

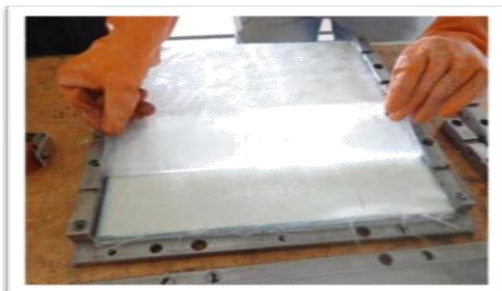


Fig 3.5: Removing the Polythene



Fig 3.6: Placing the Thermocouple Bead

Impregnated Plies are cut to the required size. The first pre-peg ply is oriented and placed upon the mould. A teflon roller is used to remove the air gaps or voids formed between layers. Now the polythene sheet is peeled from the ply. It is important that the pre impregnated material have sufficient tack so that it sticks slightly to the peel ply and to the adjacent plies. Thermocouple bead is placed on middle ply just about 3mm from the spacer clearance hole to get the exact temperature reading of the laminate. Subsequent plies are placed one upon another. These plies are stacked layer by layer of about 12 layers to attain the thickness of 5mm as per the ASTM Standard Specimen. Another surface mat is placed on the top of laminate to protect the laminate surface.

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Fig 3.7: Placing the Last Layer (Surface mat)

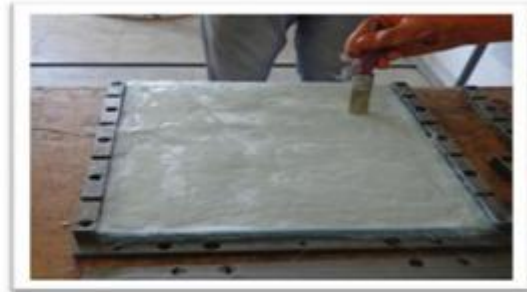


Fig 3.8: Applying Epoxy on last layer



Fig 3.8 : Placing punch plate & clamping

Then the mould is closed with punch. The mould is clamped by tightening the bolts with specified torque. Torque is applied to the clamping bolts on the tool (Mould), causing the excess resin to flow of the clearance holes. The resin flow is critical, since it allows the removal of entrapped air and volatiles from the prepreg and thus reduces the void content in the cured laminate.



Fig 3.9: Applying tightening torque on the clamping bolts of the moulds.

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Fig 3.10: Excess resin mix Flowing out Of the Mould

The mould is now placed in the oven for curing. The process of polymerization is called "curing", which can be controlled through applied temperature, chosen resin and hardener compounds; which can take minutes to hours based on the application and matrix system. Some of the chosen matrix systems benefit from external heating, whereas others simply require time long durations of time in which the required heat is produced because of the reaction between resin and hardener. The first stage in this cure cycle consists of increasing the temperature up to 80 °C and dwelling at this temperature for nearly 60 minutes when the minimum resin viscosity is reached. During this period of temperature dwell, 30KN/m Torque is applied on the tool (Mould), causing some more resin to flow of the clearance holes, indicating that the lay-up is inside has further become pliable, and takes compression. After that the oven temperature is increased to 120°C and the component is allowed to reach that temperature. Once the component has reached 120°C, a dwell of one hour is allowed. Finally the oven temperature is raised to 180°C and the component is allowed to reach it. Once the component has reached 180°C then a dwell of 4 Hrs is followed and finally it is allowed to cool for overnight. When the part is sufficiently cured, the mould is opened and the part is removed



Fig 3.11: Removing the cured laminate

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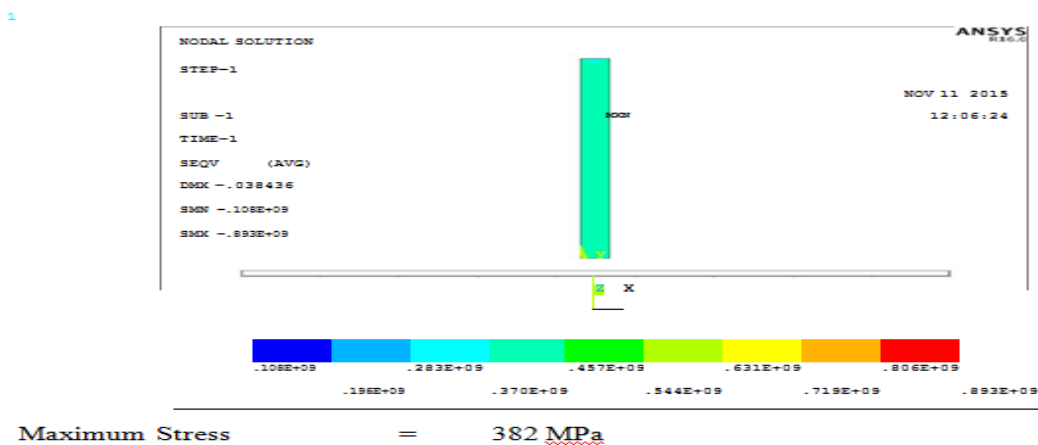


Fig 3.12: Trimming the edges of Cured Laminate

Finished moulding must usually be trimmed with a handsaw to size outside edges. Cutting Specimens: Clamp the laminate appropriately so that it does not shift during cutting. Clamp the specimen with a rubber pad (or) wooden block to absorb vibration from the operation. Begin the cut with a lower load to set the blade. Use largest appropriate blade flanges to prevent the blade from becoming distorted.

IV. TESTING & ANALYSIS

Tensile Strength



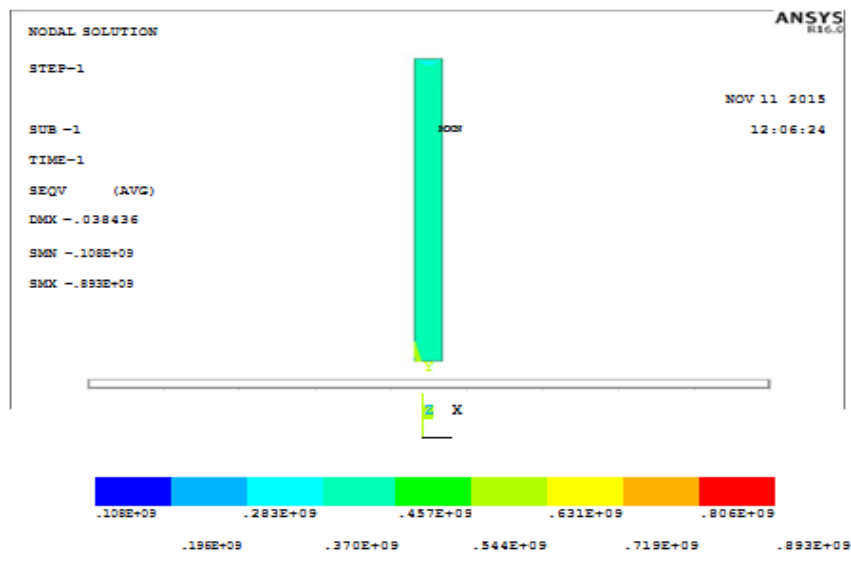
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Transverse Strength



Maximum Stress = 382 MPa

During the application, mainly the tensile strength plays a vital role. For the sake of application a pipe of 100 mm internal radius and 700 mm length is designed to withstand a pressure of 27.5 MPa. The material properties and calculations for the developed model are as follows.

GLASS EPOXY PROPERTIES

S.NO.	PROPERTY		VALUE
1	Young's modulus along fiber (E ₁) (GPa)		37.39
2	Young's modulus along fiber	(E ₂) (GPa)	7.522
3	Young's modulus along fiber	(E ₃) (GPa)	7.522
4	Poisson's ratio (ν ₁₂)		0.266
5	Poisson's ratio (ν ₂₃)		0.432
6	Poisson's ratio(ν ₁₃)		0.266
7	shear modulus(G ₁₂) (GPa)		2.759
8	shear modulus	(G ₂₃) (GPa)	2.626
9	shear modulus	(G ₁₃) (GPa)	2.759
10	Density of composite(ρ) kg/ ³		1937.6

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The formula for the calculation of helical thickness ($t_{helical}$) and hoop thickness (t_{hoop}) are given

Where P = design pressure

R = Internal radius, α = winding angle

σ = Tensile strength of composite

Now the calculations for the pipe is as follows

$\sigma = 370$ MPa

$R = 100$ mm

$\alpha = 55^\circ$ angle of winding

$\beta = 35^\circ$ i.e. $(90^\circ - \alpha)$

27.5×100

$t_{helical} = \frac{27.5 \times 100 \times (2 - 0.671)}{2 \times 370}$

$t_{helical} = 5.538$ mm

$$t_{hoop} = \frac{27.5 \times 100 \times (2 - 0.49)}{2 \times 370}$$

$t_{hoop} = 5.611$ mm

Total thickness = $t_{helical} + t_{hoop} = 5.538 + 5.611 = 11.148$ mm ≈ 11.25

Now using this calculation an analysis of the composite pipe is done using ANSYS software. The element type used is Shell 3D 8 node 281 and mesh is of mapped mesh. The thickness of each lamina is of 0.25mm. The lay-up sequence is alternate helical winding followed by hoop winding as shown in lay-up sequence figures.

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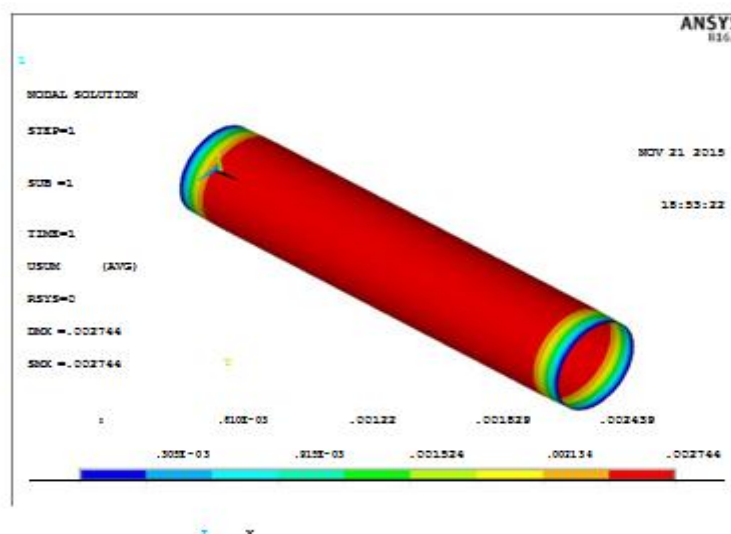
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Fig 4.1: Mesh

The resulted deformations and stresses developed because of the internal pressure are as follows. Following figure indicate the Displacement plot



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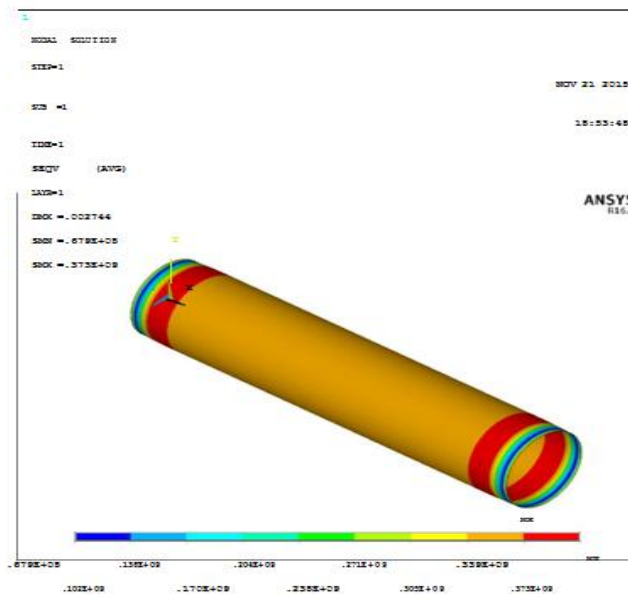


Fig : Stress plot

From the stress plot it is observed that the stress in the middle portion is of the order of 330MPa which are within the capabilities of the material.

RESULTS:

The overall tested results of all four resin systems are tabulated below

S.No.	TEST	AVERAGE STRENGTH (MPa)		
		RESIN	RESIN	RESIN
		SYSTEM 1	SYSTEM 2	SYSTEM 3
1	TENSILE TEST	282	302	372.4
2	TRANSVERSE TEST	224	242	318
3	IN-PLANE STRESS	177	185	213
4	INTER LAMINAR SHEAR	56	61	76
	STRESS			
5	FLEXURAL TEST	80	87	112

Tab: Comparison of tested results of all resin systems

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The analytical Results from ANSYS are tabulated below

S.No.	TEST	AVERAGE STRENGTH (MPa)		
		RESIN	RESIN	RESIN
		SYSTEM 1	SYSTEM 2	SYSTEM 3
1	TENSILE TEST	382	414	518
2	TRANSVERSE TEST	304	331	440
3	FLEXURAL TEST	72	83	103
4	INTER LAMINAR SHEAR	57	59	84
	STRESS			
5	IN-PLANE STRESS	369	388	449

Tab: Comparison of FEM results of all resin systems

V.CONCLUSION

The mechanical properties of E-Glass fibers are enhanced by suitable choice of matrix system . This investigation was aimed at zeroing on an appropriate epoxy resin composition from among a limited number of choices resulting the following observations\

Resin System appears to be compatible with E-Glass fibers for the sizing given on it.

As per the fig: 5.2 for resin system 1 to resin system 3 the elastic limit of resin is increasing which results in increasing strength.

The experimental investigation brings out the need for compatible matrix material particularly used in conjunction with high strength fibers.

Resin system -3 having an elastomer as its constituent and its functionality is 3.5 , whereas the other two resin systems the functionality is 2. This is a crucial factor in enhancing the compatibility of matrix with fiber.

Among all the resin compositions tried out, Resin System - 3 is most preferred one since it has given consistent values of tensile strength at an average of **375 Mpa**. This resin system is also given reasonable good flexural, transverse tensile, in-plane shear, inter laminar shear stress.

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