Mechanical Characterisation of Uni-Directional E-Glass Fiber Reinforced Composites

N. Ashoka Chakravarhi[1], Sri T. Seshaiah[2] ME, (Ph.D), Smt CH. Sandhya Rani[3]
[1]Dept of mechanical engineering
[2]Associate Professor, Dept of mechanical engineering
[3]Asst Professor, Dept of mechanical engineering
[1, 2, 3] Qis College of Engineering and Technology, Ongole, Prakasam district

Abstract- *E- Glass/ epoxy polymer composites find widespread applications because of their several advantages like high wear resistance, good strength-to-weight ratio and low cost. They find huge application in the construction of automotive and aviation body structures, in which they are inevitably subjected to various pressures during their construction, maintenance and functioning. The specimens used for drop weight testing are flat panel composite specimens. The lay-up and material used is dependent on the desired results of the testing.*

The present project work deals with the fabrication and characterization of reinforced Uni-directional woven E-glass fibre/epoxy composites enhanced by multiwalled carbon nanotubes and graphene. In the present study three process parameters were considered such as nanofillers ranging from 0.1,0.2 and 0.3 weight percentage of multi-walled carbon nanotubes (MWCNTs) and Grpahene powder(Gnps), process to disperse hybrid nanoparticles in epoxy resin and in addition to by orienting bidirectional woven E-glass reinforced woven fabric in longitudinal(00/90°) and 450 direction.

*In this work the progressive damage behaviors of hybrid woven composite panels (120*25*5 mm) impacted by Compression, Tensile and Flexural properties by a experimental. The specimens tested are made of plain-weave hybrid E- glass-fibers. The composite panels are damaged using a pres-sure-assisted instrumented Universal testing machine 25 KN.*

This work was supported in part by the U.S. Department of Commerce under Grant BS123456 (sponsor and financial support acknowledgment goes here). Paper titles should be written in uppercase and lowercase letters, not all uppercase. Avoid writing long formulas with subscripts in the title; short formulas that identify the elements are fine (e.g., "Nd–Fe–B"). Do not write "(Invited)" in the title. Full names of authors are preferred in the author field, but are not required. Put a space between authors' initials.

F. Anderson is with the National Institute of Standards and Technology, Boulder, CO 80305 USA (corresponding author to provide phone: 303-555-5555; fax: 303-555-5555; e-mail: author@ boulder.nist.gov).

S. B. Niles, Jr., was with Rice University, Houston, TX 77005 USA. He is now with the Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar. colostate.edu).

T. C. Donald is with the Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA, on leave from the National Research Institute for Metals, Tsukuba, Japan (e-mail: author@nrim.go.jp).

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. In the period of Bronze Age (3000 BC to 1000 BC), people were able to extract copper from its ore. During the Iron Age (1000 BC to AD 1860), the extraction of iron from its ores resulted in another development. Heat treatment processes were developed during this period. The general use of steel as a construction material started during this period. From 1950 onward, the era is named the Silicon Age. The development of silicon in turn resulted in the growth of electronics, computers, and automation. It is very clear from the history that the development of materials is the prime factor for the modern civilization.

1.1 Definition:

The drivers of the composite properties are properties of the constituent materials, their proportion, geometry, distribution throughout the lamina, and fiber orientation The main factors are the properties and the relative amount of constituents. Currently, various materials with different properties are available in market. We can get required properties for the composite by choosing correct constituents and appropriate proportions.

1.2 Brief History of Composites:

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.

However, humans has only 2000 years of experience in composites. The earliest example of composites are bricks made by Israelites by utilisingclay and plant straw. The Samurais of Japan made swords using laminated metals during the fifteenth century. Concrete, filled rubber, and phenolic resins were developed during the early time of twentieth century. The invention of manufacturing process to manufacture glass fibers has led to the developments in composites during the Second World War. By combining glass fibers and plastics we can get tremendous strong materials called FRP's. This material is used for making radomes of aircrafts during the start of development stage. The commercial exploitation of PMC's was because of the PMC's application in military especially in marine applications. The first commercial boat hull was introduced in 1946. The rapid growth in composites happened during the 1950s in

1.3 Classification:

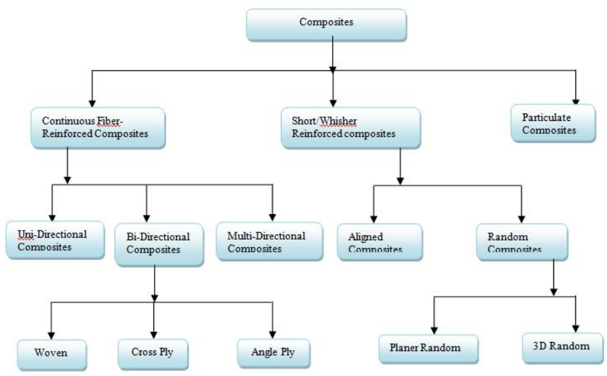


Fig 1.1: Classification of composites based on dispersed phase

1.4 Special Features of Composites:

Because of the tailorability 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

1.5 Drawbacks of Composites:

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 aluminum. It is almost 5 to 20 times more than aluminum and steel on a weight basis.
2. Designing parts with composites has lack of database

1.6 Applications of Composite Materials:

Commercial and industrial applications of fiber reinforced composites are diverse and varied. The main application areas may be broadly classified as follows:

i) **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 aluminum.

Fig 1.3: B787 Dream liner

ii) **Storage**

iii) **pressure vessels**: The shapes of different storage pressure vessel are given in Fig

Fig 1.4: Composite Cylinder With Metallic Liner

Fig 1.5: Air Vessel

1.7. Desired Properties of a Matrix:

The needs or desired properties of the matrix which are important for a composite structure are as follows:

- Reduced moisture absorption.
- Low shrinkage.
- Low coefficient of thermal expansion.
- Reasonable strength, modulus and elongation (elongation should be greater than fibre).
- Strength at elevated temperature (depending on application).
- Low temperature capability (depending on application).
- Should be easily processable into the final composite shape.
- **Dimensional stability** (maintains its shape).
- **Shrinkage** during cure,
- Modulus of elasticity,
- Ultimate elongation,

II. STATEMENT & METHODOLOGY

2.1 Scope of the work

The main scope of the work is to determine experimentally the following properties of composites with E-Glass 13mil bi-directional fabric & 3 types of Epoxy resins:

- Tensile strength
- Flexural strength
- Compression Strength

2.2 Materials Used to Prepare A Composite Laminate:

1. E-Glass Uni-directional fabric
2. Epoxy Resin
3. Hardener

2.2.1 E-Glass Fiber:

Glass fiber is a material which is formed using fine glass fibers. In history, glassmakers has experimented so much about glass fibers, but mass manufacturing of glass fibers has came to true through automation of the process and proper tooling techniques only.

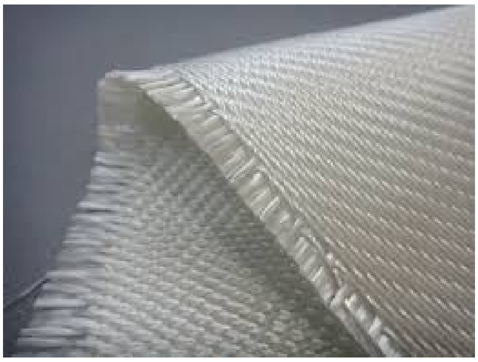


Fig 2.1 Fabric Made of Woven E-Glass Filaments

E-Glass Uni-Directional fabric Properties

Variety	: Uni-Directional fiber glass fabric
Thickness	: 0.36mm
Width	: 40"
Construction	: Warp: 48Threads / Inch
Weft	: 36Threads / Inch
Weight per Sq. Meter	: 455.4 gms
Breaking strength/50 mm	: Warp: 383 Kgs
Weft	: 258 Kgs

2.2.2. Epoxy Resin:

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.

- Low pressure requirements during fabrication
- Low shrinkage of final product
- Ease of curing methodologies with different types of hardeners

- Availability with different ranging viscosities

2.3.3. Hardener:

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 $H_2N\text{-}CH_2\text{-}CH_2\text{-}NH_2$, 1,3-diaminopropane $H_2N\text{-}(CH_2)_3\text{-}NH_2$, and hex methylenediamine $H_2N\text{-}(CH_2)_6\text{-}NH_2$.

2.3.4 Glass Fibres

Common glass fibres formed by the alumina-borosilicate glass having less than 1% w/w alkali oxides. Many types of glass fibres are there like E-glass, S-glass and C-glass fibres. Here E-significant good electrical insulator also having good strength. S-indicates this glass fibre having high silica. By adding silica to the fibre withstand high temperatures than other glass fibres.

2.4.5 Carbon nano tubes:

A carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nano scale size. Carbon tubes are formed from the essentially the graphite sheet and the graphite layer appears somewhat like a rolled-up continuous unbroken hexagonal mesh andcarbon molecules at the apexes of the hexagon. Depending on the process used for CNT synthesis, CNTs can be classified into

(i) Single-walled, double walled
(ii) Multi walled carbon nanotubes.

Single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs) are similar in certain respects but they also have striking differences. SWNTs are an allotrope of sp2 hybridized carbon similar to fullerenes. The structure is a cylindrical tube including six-membered carbon rings similar to graphite. Analogously MWNTs include several tubes in concentric cylinders as shown in Figure 1.

2.4.5.1. Properties of MWNTs:

MWNTs have excellent properties and are being employed in a large number of commercial applications. The properties of MWNTs are: Electrical: MWNTs are highly conductive when properly integrated into a composite structure. One must note that the outer wall alone is conducting; the inner walls are not instrumental to conductivity.

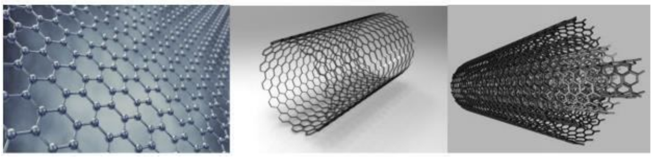
2.4.5.2 Applications of MWNTs:

There are a large number of present and evolving applications

for MWNTs. These include:

Electrically Conductive Polymers: MWNTs are suitable for these applications especially due to its high conductivity and high aspect ratio. Improved Structural Composites: MWNTs in the form of non-woven or woven fabrics or resin infused buckypaper when saturated with thermoset resins have shown considerable increase in stiffness and strength of composite structures such as structural laminates and golf club shafts for aerospace application

2.4.5.3 Graphene: It has rapidly attracted both academic interest and industrial interest because of its outstanding properties such as high surface to volume ratio, high aspect ratio, low electrical resistivity, high thermal conductivity, high strength, and modulus.



(a) Graphene (b)Single walled nanotubes (c) Multi walled nano tubes

Figure 2.2: Classification carbon nanotubes

2.5 Fabrication of E-Glass Epoxy Laminates Composites:

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 laminaeare bonded together to form a structure termed as laminate. Properties and orientation of the laminae 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 laminae.

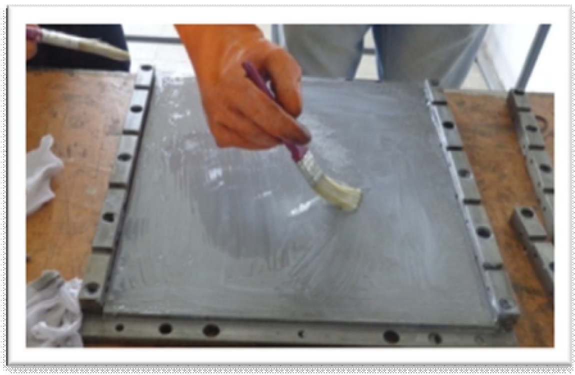
2.3 Glass fabric

2.4 Mixing Epoxy

Marking is taken by using 0° and ±45° with mould dimensions 390mmx340mm respectively.

Resin is weighed as per specifications of fabric that is 100 gms resin,pigmented (5%) for colored 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 calumating rollers or brushes for forcing resin into the fabrics.

Step 5: An optional sacrificial layer (Surface mat) is laid up on the mould surface. This layer is usually a fiberglass fabric made with the same resin system as the composite laminate. The sacrificial layer protects the laminate from surface abrasion and surface irregularities during manufacturing.



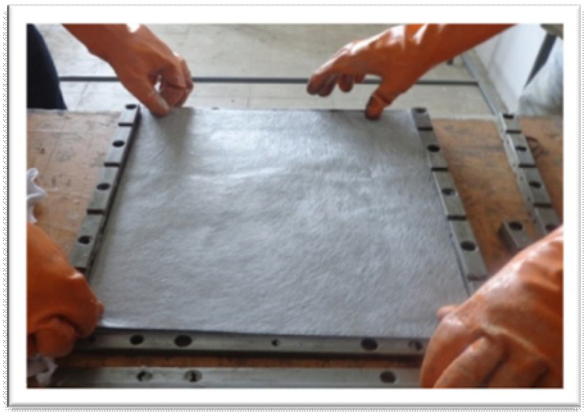


Fig 2.5 Applying Epoxy to The Mould
Fig 2.6 Placing Surface Mat

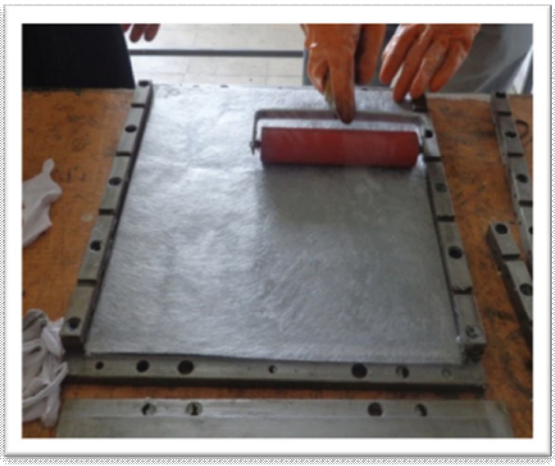


Fig 2.7 Consolidating Surface Mat
Fig 2.8 Placing the First Ply

Impregnated Plies are cut to the required size.

The first pre-peg ply is oriented and placed upon the mold.
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 3mmfrom 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.

Step 10: Then the mould is closed with punch

The mold is clamped by tightening the bolts with specified torque. Torque is applied to the clamping boltson 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

2.11 Excess resin mix Flowing out Of the Mould
Fig 2.12 Placing the Mould In The Oven

2.6 Curing:

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.

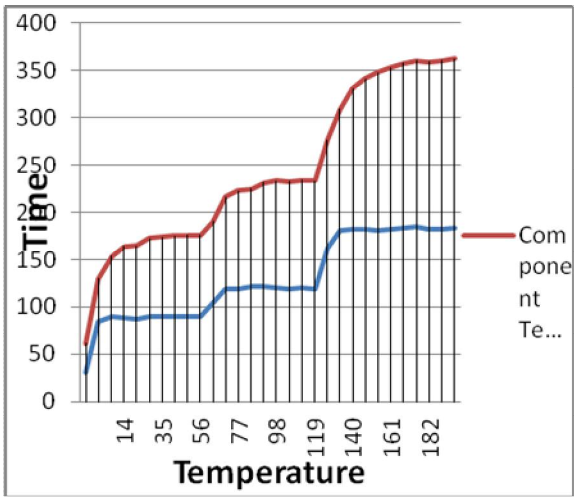
After that the oven temperature is increased to 120^{o}C and the component is allowed to reach that temperature. Once the component has reached 120^{o}C, a dwell of one hour is allowed. Finally the oven temperature is raised to 180^{o}C and the component is allowed to reach it. Once the component has reached 180°C then a dwell of 4 Hrs is followed and finally it is allowed to cool for overnight.

The format of data collected for each mould during curing.

Table 3.2 Part curing cycle data

Time	Oven Temperature	Component Temperature
0	30.5	31
15	84	46
30	89.55	64
45	88	76
60	87.9	77
105	90	85
120	90	86
135	90.1	86
150	104.5	86
165	119	97
180	119.5	103
210	121	110
225	120.5	113
240	119.5	113
255	120	114
270	119.5	114
285	163	114
315	181.5	149
330	181.5	160
405	182	177
420	182.5	178
435	183.5	179

The following graph shows heating time variation b/w laminate oven:



Graph 1

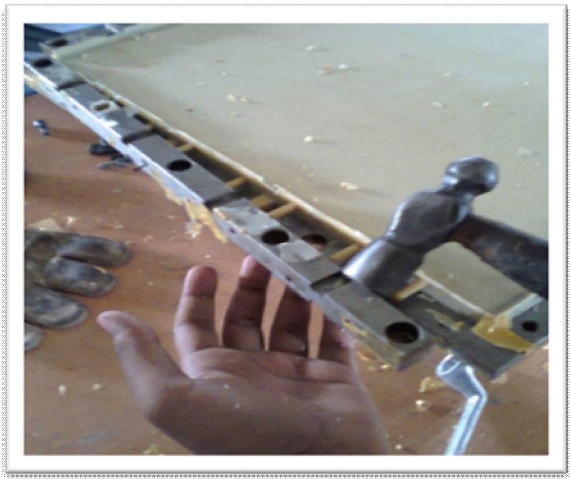


Fig 2.13 : Removing the cured laminate

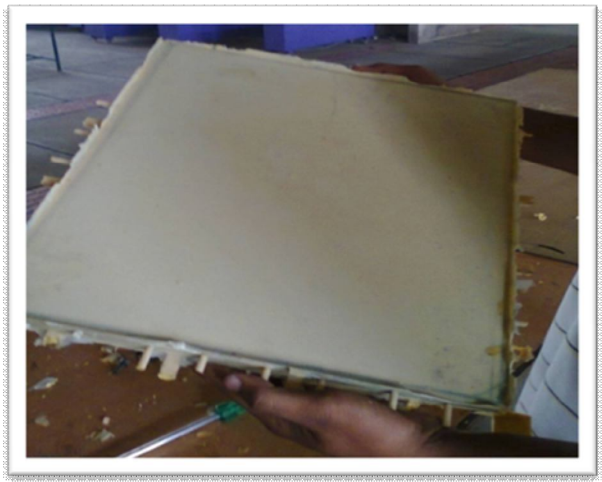


Fig 2.14 Cured Laminate

2.7 PREPARATION OF TABBED SPECIMENS:

Finished molding must usually be trimmed with a handsaw to size outside edges.

2.8 Cutting Specimens:

1. Clamp the specimen with a rubber pad (or) wooden block to absorb vibration from the operation.
2. Begin the cut with a lower load to set the blade.
3. Use largest appropriate blade flanges to prevent the blade from becoming distorted.

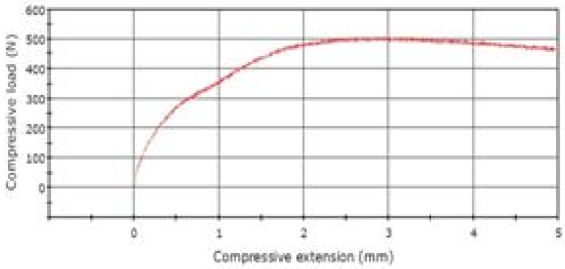
The laminate fabricated is cut as per ASTM-D3039 (length 250mm and width 15mm) using Handsaw.

III. EXPERIMENTAL RESULTS AND DISCUSSION

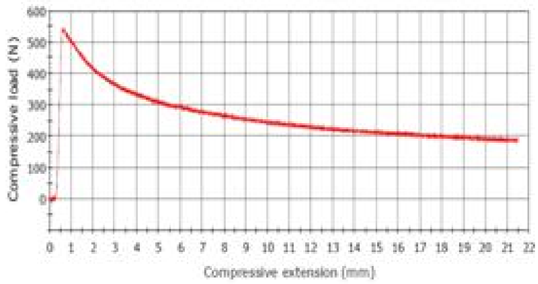
3.1. Test Procedure:

A fixture is used to align the specimen in the wedge grips and the grips are therefore tightened.

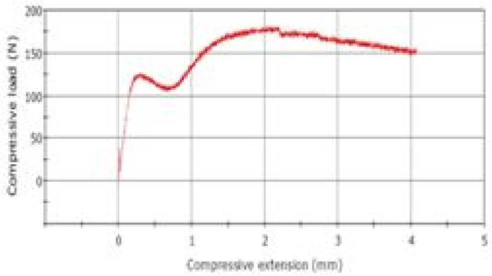
The wedges are inserted into the compression fixture. The specimen is compressed to failure.



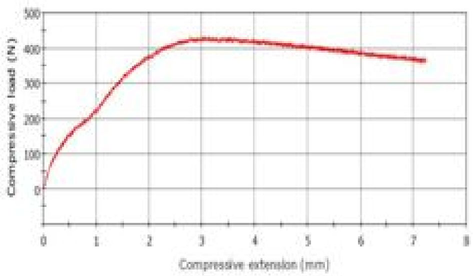
Graph.1. Compressive extension Vs Compressive load of 0.1% wt of MWCNTs



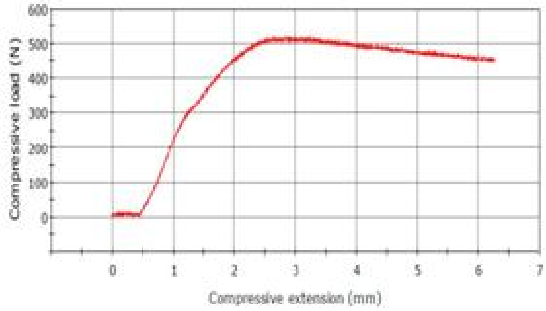
Graph.2. Compressive extension Vs Compressive load of 0.2% wt of MWCNTs



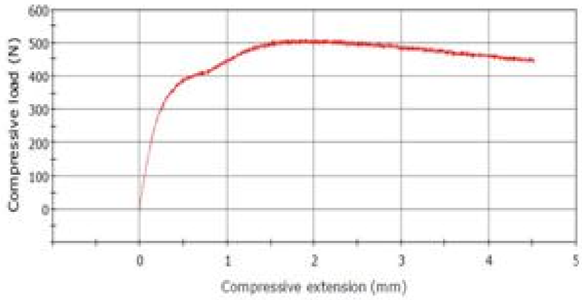
Graph.3. Compressive Load Vs Compressive extension of 0.3% wt of MWCNTs



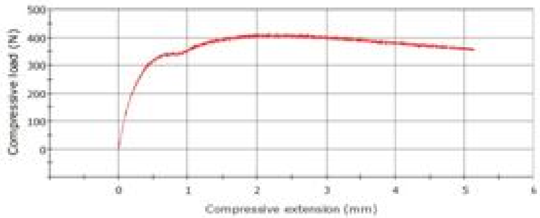
Graph.4. Compressive Load Vs Compressive extension of 0.1% wt of GNPs



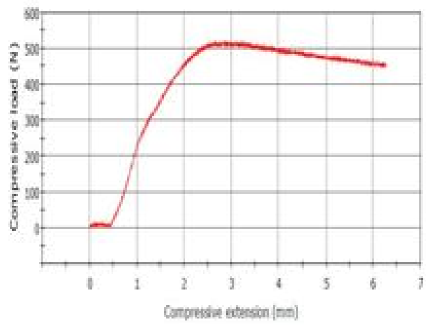
Graph.5. Compressive Load Vs Compressive extension of 0.2% wt of GNPs



Graph.6 Compressive Load Vs Compressive extension of 0.3% wt of GNPs

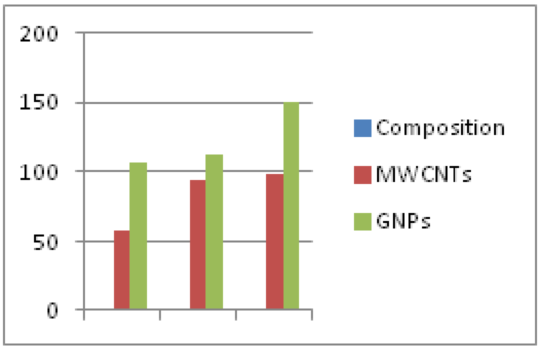


Graph.7.Compressive Load Vs Compressive extension of 0.1% wt of MWCNTs/GNPs



Graph.8. Compressive Load Vs Compressive extension of 0.2% wt of

MWCNTs



Graph.9. Compressive Load Vs Compressive extension of 0.3% wt of MWCNTs/GNPs

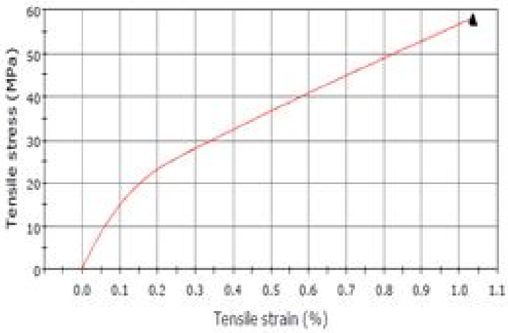
Graph10: The comparison of MWCNTs, GNPs and MWCNTs/GNPs with different composition

TABLE 3.1: The comparison of MWCNTs, GNPs and MWCNTs/GNPs with different composition

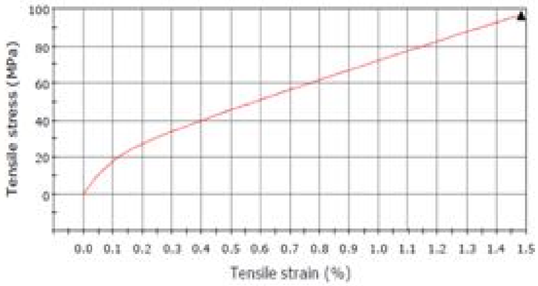
position	t %	t %	t %
CNTs	0	0	0
NPs	5	0	0
Ts/GNPs	0	0	0

3.2. TEST PROCEDURE:

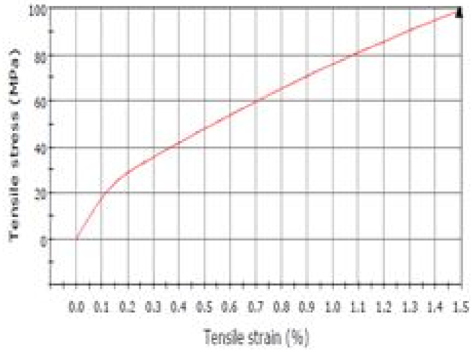
Tensile test s are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared tensile properties often are used to predict the behavior of a material under loading tension.The test specimen is subjected to the jaws of the **instron 8801.**



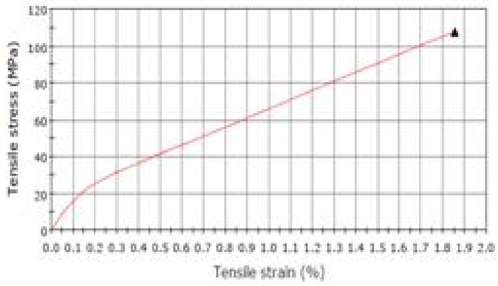
Graph.11. Tensile stress Vs Tensile Strain of 0.1 wt % GNPs



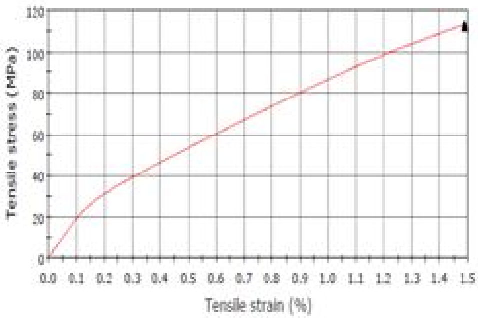
Graph.12. Tensile stress Vs Tensile Strain of 0.2 wt % GNPs



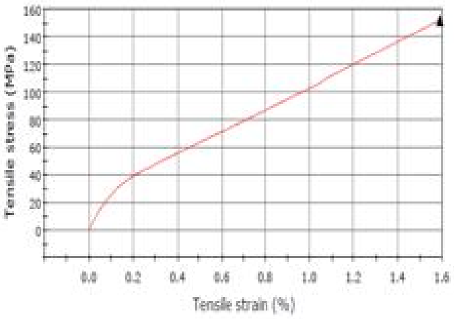
Graph.13. Tensile stress Vs Tensile Strain of 0.3 wt % GNPs



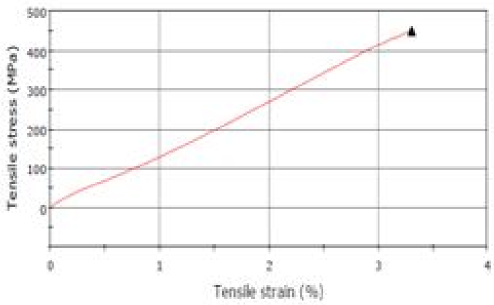
Graph.14 Tensile stress Vs Tensile Strain of 0.1 wt MWCNTs



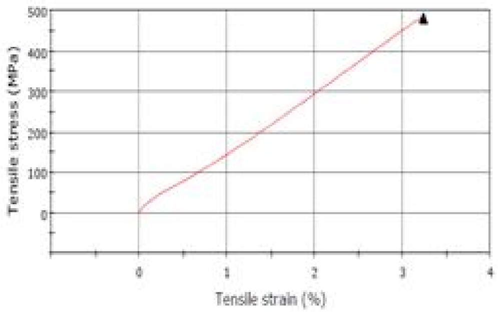
tensile stress Vs Tensile Strain of 0.2 wt % MWCNTs



T ensile stress Vs Tensile Strain of 0.3wt % MWCNTs

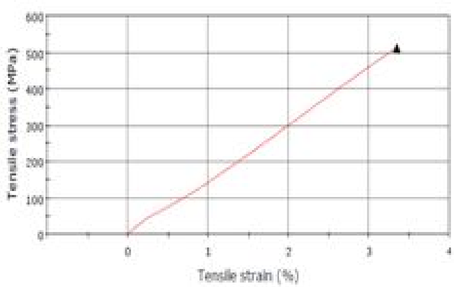


Tensile stress Vs Tensile Strain of 0.1 wt % MWCNTs/GNPs

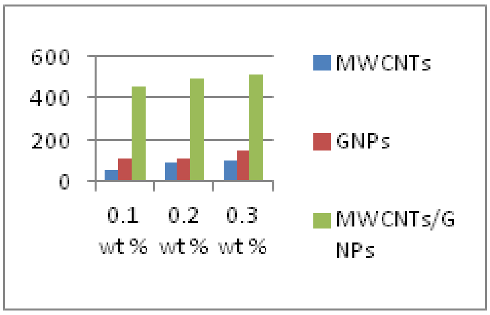


Graph.17.

Graph.18. Tensile stress Vs Tensile Strain of 0.2 wt % MWCNTs/GNPs



Graph.19. Tensile stress Vs Tensile Strain of 0.3 wt % MWCNTs/GNPs



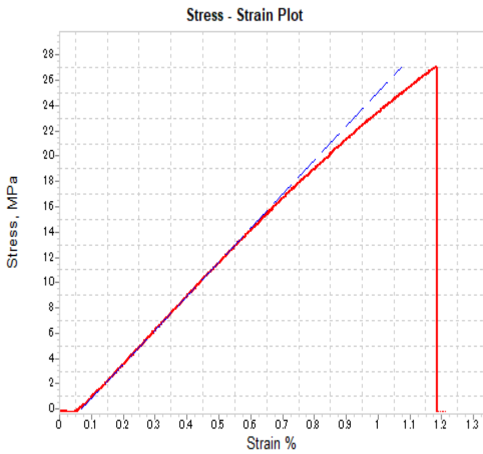
Graph 20: The comparison of MWCNTs, GNPs and MWCNTs/GNPs with different composition

position	t %	t %	
/CNTs	3	4	
NPs	7	12	
Ts/GNPs	4	90	

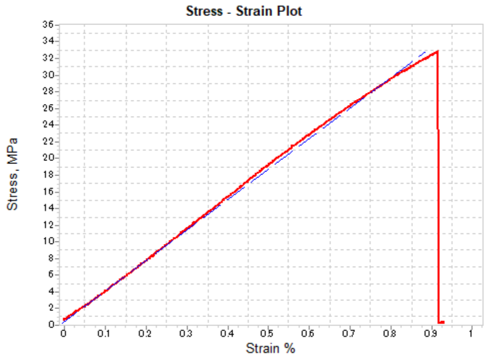
TABLE 3.2 : The comparison of MWCNTs, GNPs and MWCNTs/GNPs with different composition

3.3. TEST PROCEDURE:

Flexural strength, also known as modulus of rupture, or bend strength, transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique.



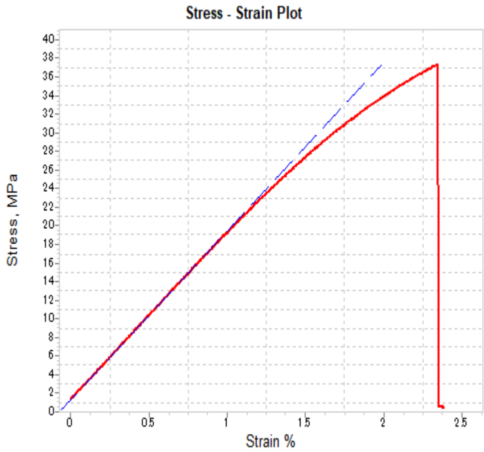
Flexural stress Vs Flexural Strain of 0.1wt % MWCNTs



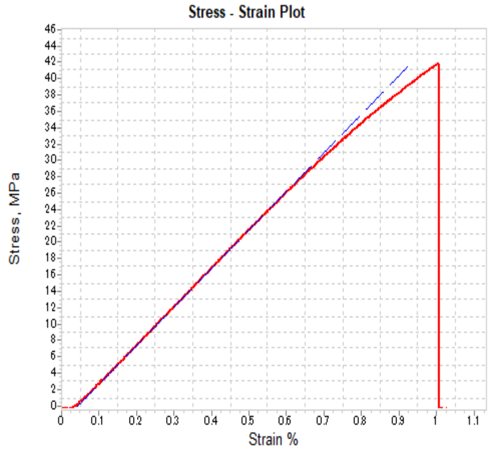
Graph.21.

Graph.22. Flexural stress Vs Flexural Strain of 0.2 wt % MWCNTs

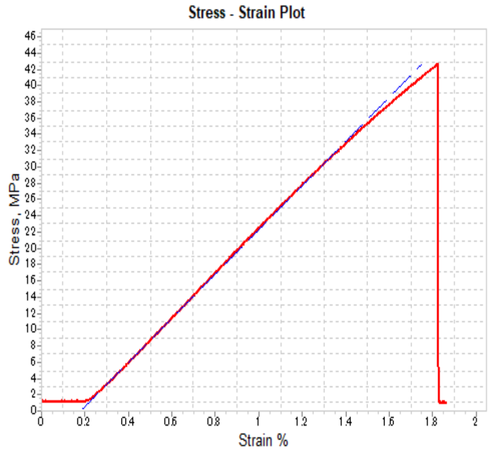
Graph.23.Flexural stress vs Flexural strain for 0.3% wt MWCNTs



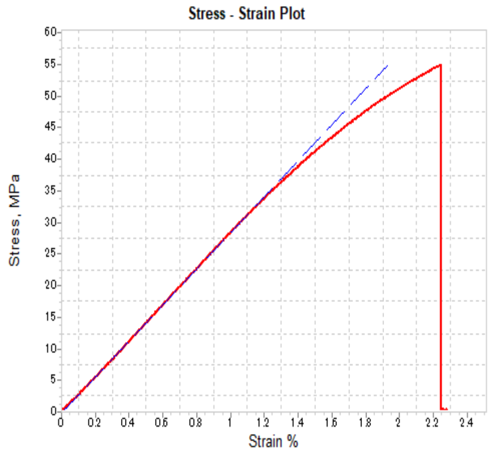
Graph.24. Flexural stress Vs Flexural Strain of 0.1wt % GNPs



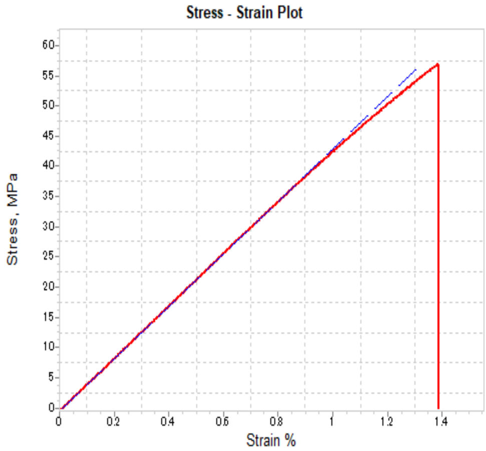
Graph.25. Flexural stress Vs Flexural Strain of 0.2wt % GNPs



Graph.26. Flexural stress Vs Flexural Strain of 0.3wt % GNPs

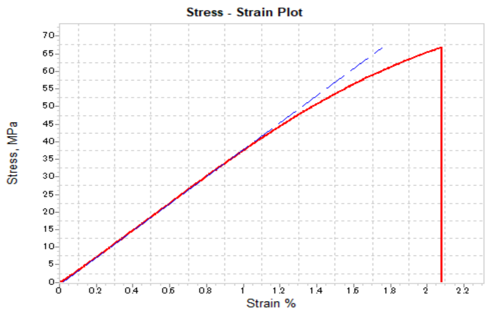


Flexural stress Vs Flexural Strain of 0.1wt % MWCNTs/GNPs

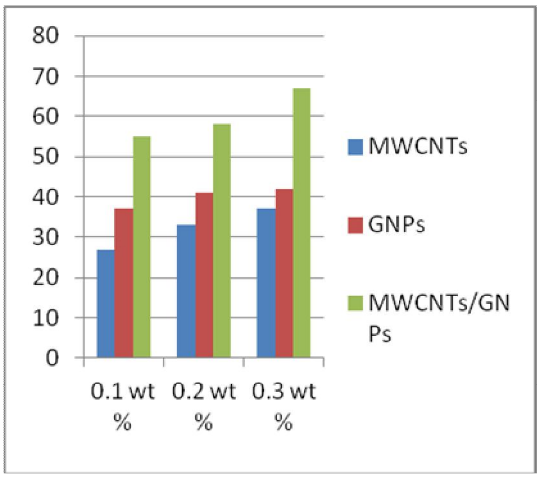


Graph.27. F

Graph.28. Flexural stress Vs Flexural Strain of 0.2wt % MWCNTs/GNPs



Graph.29. Flexural stress Vs Flexural Strain of 0.3 wt % MWCNTs/GNPs



Graph.30. comparison NPs, MWCNTs/GNPs with different composition

position	rt %	rt %	rt %
/CNTs	7	3	7
NPs	7	1	2
Ts/GNPs	5	8	7

IV. CONCLUSION

Full advantage of the enhanced mechanical properties of the fibers like E-Glass can be fully exploited if a judicious choice of matrix system is made. This investigation was aimed at zeroing on an appropriate epoxy resin composition from among a limited number of choices resulting the following observations

4.1.Conclusion of compression Test:

From the above graph we concluded that In MWCNTs laminates composition of 0.1 wt% has the more strength as compare to the remaining. if the percentage increases then the strength is decreasing. In the case of GNPs 0.3 wt% composition specimen have the high strength, if the percentage increases then only its strength is increasing. The combination of both MWCNTs and GNP s 0.3 wt % of specimen have the high strength, if the percentage increase then only the strength is increasing.

4.2. Conclusion of Tensile Test:

From the above graph we concluded that in the MWCNTs the 0.2 wt % composition of specimen have high strength, if further add the mixture then its strength is decreasing. In the GNPs the 0.2 wt% composition of specimen have high strength, if further composition is increased then the strength is decreasing. In the combination of MWCNTs and GNPs the 0.1 wt% of specimen have high strength as compare to the remaining. if further mixture increases then its strength is decreasing

.

4.3 Conclusion of Flexural Test:

From the above graph we concluded that 0.3 wt % specimen of MWCNTs have high strength as compare to the remaining, if further composition increases its strength is decreasing. The GNPs of 0.1 wt% of composite specimen have high strength; if further composition increases then its strength is decreasing. In the mixture of MWCNTs and GNPs the 0.2 wt % composite specimen have high strength as compare to the remaining. If further increase the composition then its strength is decreasing.

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