STUDY ON FACTORS AFFECTING ON TENSILE STRENGTH AND MICRO STRUCTURES OF HYBRID NANOCOMPOSITES PREPARED BY E-GLASS/EPOXY AND MULTI WALLED CARBON NANO TUBES.

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Abstract: Multi walled Carbon nanotubes (MWCNTs) are creating a center of attention in scientific and industrial attention by good feature of their distinctiveness. Present research is on Fabrication and depiction of E-Glass Fiber Composites developed by MWCNTs. The Factors deemed for present problem are Weight of MWCNTs, Methodology to disperse MWCNTs in epoxy, Orientation of the E-glass fiber. Fabrication of E-Glass Fiber Composites was carried out with respect to the ASTM standards D3039-76 and Tensile Testing was performed. The results show that the nano-particulated composite plate can be manufactured by considering less nano-particles stirred with probe sonicator and plied up with hybrid orientation.

Index Terms – **Carbon Nanotubes, Composite material, Charecterization of materials.**

I. INTRODUCTION

In this present era, the demand and usage of FRP composites was increasing in rapid manner. The applications of these composites are not limited to a field, but it is widely spread over to various areas. The field of applications includes automotive, sporting goods, aerospace, structural, cryogenic vessels, solar panels and oil and gas pipelines. Incorporation of nanofillers into the polymer matrix has been an active area of research around the world. Moreover, their properties can be tailored according to the specific requirement. However, polymer composites commonly used in space industry are intrinsically poor conductor (transparent to EM radiations) and need some sort of conductive filler to make them conductive. Alternatively, electrically conducting polymers are available but they are quite expensive, difficult to process and have relatively poor mechanical properties [2]. Recent trend is to disperse conductive nanofillers in the insulating matrix to make 3-dimensional electron-conduction network. The nanofillers can easily form a conductive network inside the host matrix due to high aspect ratio. Among various types of nanofillers, carbon based nanofillers have received great interest because of their novel properties [3]. Carbon nanotubes (CNTs) offers multifunctional properties consequently current trend is to add them into polymer to produce innovative nanocomposite material. Large aspect ratio, high intrinsic electrical conductivity and high mechanical strength make them an excellent choice for creating conductive nanocomposites for high-performance shielding material. Reproduction of the distinct behaviors of nano-fillers in the polymer matrix is one of the crucial objective to achieve better mechanical, electrical and/or thermal properties. The usage of CNT as nanofillers is due to its strength (about 22 GPa [3]) and modulus (about 1 TPa [4]). Various researchers have studied on the mechanical performance of GFRP composites and incorporation of different nanofillers [5–7] at various environments and loading conditions [8–11]. There is a dearth in the literature of tensile behavior of CNT embedded into polymer matrix with crosshead speed variations.

II. LITERATURE SURVEY

Carbon Nanotubes (CNTs) have high potential to improve the properties of polymers. The key factors for properties improvement of polymer/CNT nanocomposites are good dispersion and low agglomeration [1–4]. Consequently, two approaches have been proposed to disperse CNT in polymer matrix: application of stresses to break mechanically the agglomerates and obtain adequate dispersion and surface treatments of CNT based on chemical and physical methods [5–10]. According to Coleman et al. [3] well dispersed CNT is of utmost importance to maximize the interfacial area, to achieve efficient load transfer and minimize the presence of stress concentration centers. The frictional forces in polymer/CNT interfaces are expected to be large and, even if debonding has occurred, there will be significant load transfer from the polymer to the CNT, contrary to traditional fiber reinforced composite, where complete debonding implies failure of the composite [11–14]. According to Huang et al. [14] good dispersion can be seen at low concentrations of CNT and they re-aggregate after long period of time. At concentrations above the threshold (2–3 wt %) an elastic gel of tentangled CNT has been observed. Furthermore, high concentration of CNT in epoxy increases resin viscosity and makes the dispersion of CNT extremely difficult [15]. Compatible surface treatment of CNT with the epoxy matrix has been found to give good stress transfer at the interface [4]. An effective dispersion of CNT requires overcome inter-tube attraction, separating CNT from aggregates and stabilizing them within the polymer matrix. In order to optimize the dispersion of CNTs in a polymer matrix chemical surface treatments can be used together with mechanical dispersion methods (ultrasonication, calendering, ball milling and shear mixing) [10–17]. Direct covalent treatment is associated with a change of hybridization from sp2 to sp3 and a simultaneous loss of ð-conjugation system in CNT. This is achieved by processes such as: fluorination, hydrogenation, cyclo-addition, oxidation and further derivative reactions. Defect sites on CNT surface like: open ends, holes in the sidewalls, irregularities in CNT scaffold, are utilized in order to

tie up different functional groups. Oxidation can be obtained by wet chemical methods with concentrated acids or by milder approaches using the photo-oxidation, oxygen plasma, or gas phase treatment. [10,18–30]. Covalent treatments greatly enhance the solubility of CNT and can provide multiple and strong bonding sites to the polymer matrix. It is believed that the improvements in nanocomposite properties are addressed in connection with improved dispersion and efficient load transfer via epoxy/CNT interface. However, this route can strongly influence the intrinsic characteristics of CNT and result in fragmentation and degradation of CNT structure, which further reflects in the overall performance of polymer/CNT nanocomposites [7,15]. Table 1 summarizes the main literature based experimental results and emphasizes the effect of covalent treatment for MWCNT on the thermo-mechanical properties of epoxy nanocomposites. It can be noticed that small amounts of covalent treated MWCNT (in most cases less than 1 wt %) have a positive effect on thermo-mechanical properties of epoxy nanocomposites. The results show an average increase of 40%–50% in modulus and strength and an average increase of 20% of Tg, compared to neat epoxy. Covalent treated MWCNT also improved the toughness of nanocomposites. In addition, amino-functionalization seems to be a usual surface treatment of CNT due to its high reactivity with epoxy resin [29]. Non-covalent treatments are an efficient alternative route to functionalized CNT and yet preserving the intrinsic characteristics of CNT and ð–conjugation system. In addition, this route leads to higher efficiency of the functionalization, compare to covalent treatments where VDW active sites on CNT surface are limited (mostly at the defects and end caps). There are three main methods for non-covalent CNT treatments: (a) polymer wrapping; (b) surfactant adsorption and (c) endohedral method. Polymer wrapping process is achieved through the interactions and ð–ð stacking between CNT and polymer chains containing aromatic rings. The surfactants studied are classified according to the charge of their head groups: nonionic, anionic and cationic. In general, ionic surfactants have some advantages in water-soluble polymers, while nonionic surfactants are proposed in case of water-insoluble polymers. There are three possible surfactant-CNT interaction mechanisms: (a) electrostatic attraction or repulsion; (b) hydrogen bonding between the –O– of polyethoxylate and –OH and/or –COOH groups of CNT and; (c) hydrophobic and π-π interactions. According to Vaisman et al. [8] it is important to achieve mechanical dispersion of CNT prior to surfactant adsorption in order to obtain an efficient de-agglomeration of CNT.

III. MATERIALS AND METHODS

3.1 Testing Materials

The polymers are substances, which consists of long chains or networks, built up by the repeated linkage of small reactive molecules. Plastics, rubber, adhesives, coatings, fibers with a clearer understanding of the chemistry and physics of these materials it has become possible to combine them with fibers in order to produce an enormous range of unknown substances which are loosely referred to as "advanced composites" [13].

Polymer Matrix Nanocomposites

In the simplest case, It should be noted that the improvement in mechanical properties may not be limited to stiffness or strength. Time-dependent properties could be improved by addition of the nanofillers [12]. Alternatively, the enhanced crystallization behavior under flow conditions and other physical properties of high performance nanocomposites may be mainly due to the high aspect ratio and/or the high surface area of the fillers, since nanoparticulates have extremely high surface area to volume ratios when good dispersion is achieved. Nanoparticle dispersibility in the polymer matrix is a key issue, which limits the applicable particle volume fraction and there for also the multi-functionality of the composite material.

The E-glass fiber is considered in the present study with a size of 600 yields (600 yards in one pound of material) and the Multi-Walled Carbon Nanotubes with properties given in table 1 were considered for present study. The room temperature curable Epoxy Resin LAPOX L-12 and Hardener K-6 are used as matrix material in the experimentation

Material	Specific gravity	Tensile strength MPa (ksi)	Compressive strength MPa (ksi)
Polyester resin (Not reinforced)	1.28	55 (7.98)	140 (20.3)
Polyester and Chopped Strand Mat Laminate 30% E-glass	1.4	100 (14.5)	150 (21.8)
Polyester and Woven Rovings Laminate 45% E-glass	1.6	250 (36.3)	150 (21.8)
Polyester and Satin Weave Cloth Laminate 55% E-glass	1.7	300 (43.5)	250 (36.3)
Polyester and Continuous Rovings Laminate 70% E-glass	1.9	800 (116)	350 (50.8)
E-Glass Epoxy composite	1.99	1,770 (257)	-
S-Glass Epoxy composite	1.95	2,358 (342)	-

3.2 Preparation of GFRP and CNT enhanced GFRP laminates
Nanocomposite Preparation by Magnetic Stirrer

The uniform dispersion of MWCNTs in polymers is a big challenge, so Ball Milling, Ultrasonication, Magnetic Stirring, High Speed Mechanical Stirring are the preferable processes for uniform dispersion of MWCNTs. According to the combinations designed in table 4, The Magnetic Stirrer was operated for 20 minutes with a gradual speed increase from 30 RPM to 320 RPM with heating to about 40-80°C as shown

in figure 1.. After 20 minutes the hardener was added to the dispersion for another 5 minutes with heating turned off. This Epoxy resin was the applied on the fiberglass sheets by Hand-layup method by using the mold of 150x150x3 mm size and was left for proper curing. Hence the 4 different combinations (1, 2, 5 and 6) were prepared

Nanocomposite Preparation by Probe Based Sonicator

Apart from the earlier method of using a magnetic stirrer to prepare the matrix, as designed in table 5 the probe based Sonicator is also used. The figure 2. Shows the set up for probe based Sonicator nano particles mixing method. According to the combinations designed in table 5, epoxy resin was first mixed by mechanical stirring for 5 minutes with a glass rod. Then this mixture was sonicated for a total time of approximately 40 minutes.

This Epoxy resin was the applied on the fiberglass sheets by Hand-layup method by using the mold of 150x150x3 mm size as shown in figure 3 and was left for proper curing. Hence the 4 different combinations (3, 4, 7 and 8) were prepared

Specimen Preparation

After the fabricated Composite Plate had been removed from the mould, the

Tensile Test :

Tensile Testing was carried out on the specimens by using U.T.M. with Cross Head Speed 10 mm/min. The test was performed in accordance to the ASTM D3039 standard samples as shown in fig 3 to evaluate the tensile properties. The samples were tested at room temperature with different loading rates.The experimental set up is as shown in figure 4.

Specimen's were prepared according to ASTM D3039-76 standards [15]. Individual Specimens were cut out after marking them accordingly. Dimensions of the individual specimens are shown in the figure.

Fig 1. Composite Plate after Fabrication by Resin prepared by mechanical stirrer.
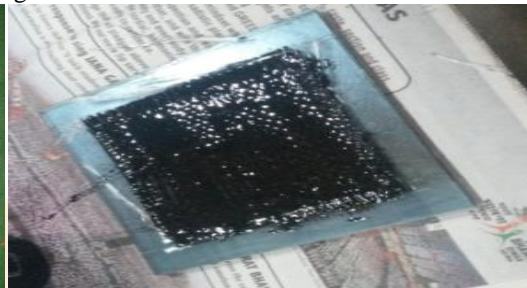
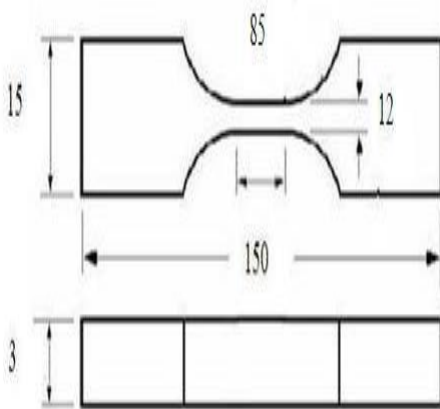*Fig 2. Composite Plate after Fabrication by Resin prepared by probe sonicator*

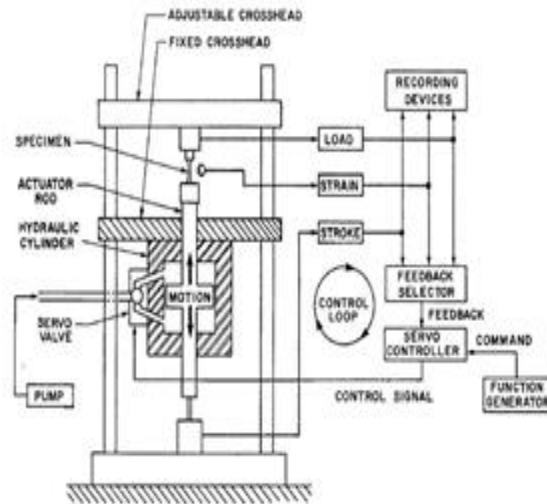*Fig 3 Dimensions According to ASTM D3039 Standard*

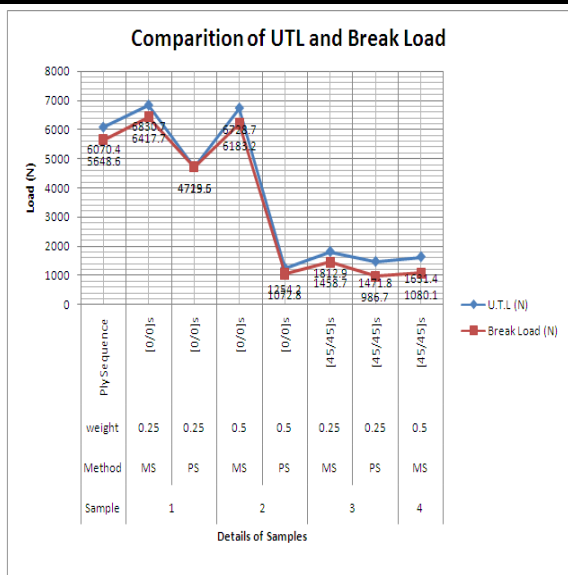*Fig 4. Experimental set up for tensile test.*

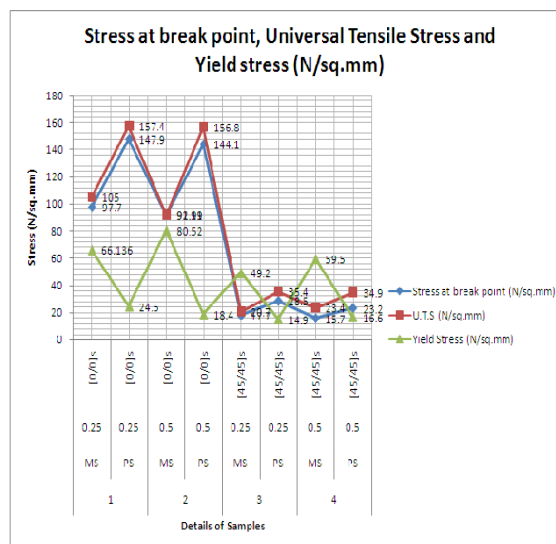Figure 5. Tensile test Results for Nano-composites
(UTL & Break load)

Figure 6. Tensile test Results for Nano-composites
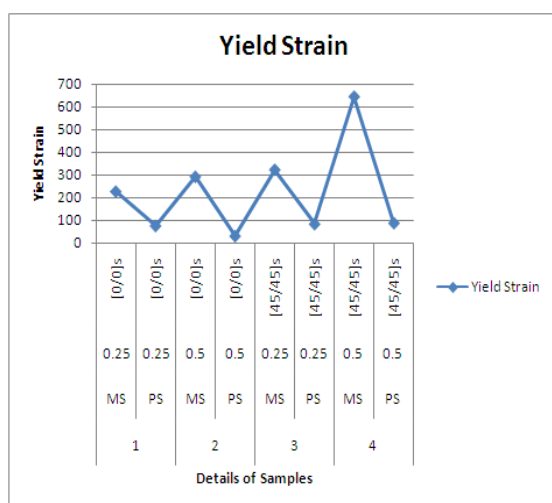(Break point, UTS & Yield stress).

Figure 7. Tensile test Results for Nano-composites (Yield Strain).

As observed from the test results the figure 5a, figure 5b and figure 5c indicates that maximum universal load bearing capacity is observed with 0.25 grams nanoparticals mixing by probe sonicatorwith ply-up sequence [0/0]s. Maximum stresses at break point were indicated with 0.25 grams nano-particles mixing by probe sonicator with ply-up sequence [0/0]s, so that with these factors the life of the nano-composite plate is increased. The Maximum tensile strength and maximum break load capacity were also observed for 0.25 grams nano-particles mixing by probe sonicator with ply-up sequence [0/0]s. The maximum yield stresses were observed for 0.5 grams nano particles mixing by magnetic stirrer with ply-up sequence [0/0]s where as the minimum yield stresses were observed for 0.25 grams nano-particles mixing by probe sonicator with ply-up sequence [45/45]s. The maximum yield strains were observed for 0.5 grams nano particles mixing by magnetic stirrer with ply-up sequence [45/45]s where as the minimum yield stresses were observed for 0.25 grams nano-particles mixing by probe sonicator with ply-up sequence [0/0/0/0].

The test results for specimen's prepared by magnetic stirring do not yield proper strength as required. The reasons may be improper dispersion of MWCNT's in the epoxy resin, Due to heating the epoxy resin has lost its properties, improper bonding of the MWCNT's and epoxy resin with the fiber glass. So by observing the above discussions it has to be concluded that for minimum yield stresses and strains the nano-particulated composite plate can be manufactured by considering 0.25 grams nano-particles mixed with probe sonicator and plied up with hybrid orientation [0/45]s.

IV. CONCLUSIONS

The manufacturedhybridnano-composites with dissimilarity in the preparation of matrix with MWCNTswere tested and micro-structural study was carried out. The experiments conducted on hybrid nano-composites show that there will be an increase in Universal tensile strength when properly mixed and also can upholdbetter break loads. By the test results achieved we find that dispersion of the MWCNTs in the Epoxy resin plays a major role in deciding the strength factor of the composite material. It tends to create the bonding between matrix and the E-glass fiber sheets which helps to increase the tensile strength of the hybrid nano-composite material. It is observed that the delamination and fiber breakage are minimal when the carbon nanotubes are properly mixed using a probe Sonicator rather than the magnetic stirrer. The fiber pullout and delamination are observed majorly in the 0° oriented specimens. By observing the above discussions it can be concluded that for minimum yield stresses and strains the nano-particulated composite plate can be manufactured by considering 0.25 grams nano-particles mixed with probe sonicator and plied up with hybrid orientation [0/45]s

Name	Resolution for microstructures		
	0.1 microns	0.25 microns	0.65 microns
Epoxy			
Epoxy with MWCNT (Mechanical stirring)			
Epoxy with MWCNT (probe sonicator)			
Glass/epoxy Nanocomposite with MWCNT (Mechanical stirring)			
Glass/epoxy Nanocomposite with MWCNT (probe sonicator)			

V. REFERENCES

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