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Mechanical Characterization of GFRP with Graphene Nano Filler

Yadhu krishnan U[1], Dr. Suresh K S[2]

PG Student, Department of Mechanical Engineering, NSS College of Engineering, Palakkad, Kerala, India[1]

Professor, Department of Mechanical Engineering, NSS College of Engineering, Palakkad, Kerala, India[2]

Abstract: Polymer matrix composite have a important role in large no of industries ranging from automobile to aerospace. Due to their extremely good Strength to weight ratio when compared to conventional monolithic metals. One of the limitation regarded with them is the low mechanical properties as by existence of polymer associated. So as a material that will be crucial in every field due to its potency there is a need to increase its mechanical properties. The opportunity to achieve these improvements is emerging with the appearance of Graphene, a Nano-filler material. In this paper investigation on the effect of Graphene Nano-filler on Glass fibre-reinforced polymer are presented. Fabrication of E-glass fibre-reinforced Graphene Nano filled composites are done using hand layup technique. The composite specimen was created with varying weight percentage of Nano-filler content Ranging ranging from 0.5 % to 1.5 %. A specimen without Graphene filler was also constructed. For consideration of Agglomeration Ultra Sonicator was used for the mixing of Resin and Nano-filler. Tensile test, Flexural test, Short beam bending test were carried on the test specimen. From the experimentation it's been found Graphene as a filler has only positive effect on the mechanical properties of GFRP, as tensile strength, Flexural strength, Interlaminar shear strength all seems to be increasing with addition of Nano-filler when compared to Conventional GFRP specimen. Highest material properties are achieved with highest weight percentage of graphene which is 1.5 %, indicating property values are directly proportial to Weight percentage of Nano-filler. It's also understood Agglomeration of filler content on interface is a crucial process need to be stopped during fabrication as it can have a adverse effect on the properties, as by the reduction of flexural strength going from 0 % to 1 % filler content. Overall, the work demonstrated effectiveness of Graphene as a Nano-filler to enhance the mechanical properties of GFRP.

Keywords: Composite**,** GFRP, Nano filler, Graphene**.**

I. INTRODUCTION

In the past, the Requirement for fiber reinforced composite laminates such as Carbon Fibre Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP) and Fiber Metal Laminates (FML) is sharply Growing. Fiber reinforced polymer (FRP) is created by a combination of matrix and fiber-reinforcement, where strong but brittle fibre provides high strength while the matrix phase reduces stress concentration, absorbs energy and provides high fracture toughness. As a outcome, composite laminates can provide superior mechanical properties of high levels of strength-to-weight ratio, stiffness-to-weight ratio, fracture toughness and corrosion resistance. Due to these advantages, the composite laminates have extensive applications in various manufacturing fields such as aeronautics, aerospace, marine, automobile, medical service, chemical processing equipment and sporting goods. Taking aerospace as an sample For instance, about 57% of the primary structure of Boeing 787 (Dream-liner) consists of composites, which can save 15–20% fuel for a comparable mission compared to any other wide body airplane. considering aero engines, both the fan cases and blades in compressor's cooler section of Aviation unit are fabricated from CFRP, which can provide 25% reduction in operational cost, 16% lower emissions and 170 kg weight reduction.

II. LITERATURE

Polymers are the most desired materials due to their low cost, reproducibility, easy processing. Polymer Nano composites is a combination of polymer matrix and with a large range of filler materials both, organic or inorganic which have at least one dimension of nanometer range. In past there has been a great expansion in research related to the polymer nanocomposites due to development of advanced materials for potential applications. [1]. Graphene, have captured interest with remarkable properties such as virtually indestructible structural integrity, ultimate insulation and antibacterial qualities [2] . Discoveries paving the way for intriguing applications. Among the generally used reinforcing materials, glass fibers are the most often utilized. The usage of GFRP composites are gradually increasing day by day because of its unique properties over conventional metals. GFRP composite materials are much stronger and contain less weight than the metals which are using in more industries like Automobiles and aircraft [3]. And it was noticed that the properties of the GFRP composites are decreasing noticeably in certain conditions. So, it is important to improve the quality and mechanical properties of the GFRP composites. Novoselov KS et al [4] studied importance of graphene nano fillers used as reinforcement in composite. Its described Graphene, a 2D nanomaterial, possesses exceptional physical properties due to its pure sp^2 hybridization network. and have excellent mechanical properties,

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exceptional electrical and thermal conductivity. making it a promising material for various applications like the fields of aerospace, manufacture of flexible super capacitor electrodes, and in artificial muscle and tissue engineering. Since it was produced and characterised in 2004 by Geim and Novoselo, graphene has become a hot topic and attracted attention globally.

When graphene was produced, it impressed the scientific community with its remarkable flexibility. Researchers then became interested in exploring its mechanical properties and expected that it could be as strong as the CNT. Yang H et al [5] discussed problems that still affect the incorporation of nanoparticles content into polymer matrices which is tendency for them to agglomerate. In order to homogenize the system more and to achieve a highly well-dispersed nanocomposite, a possible route is modification of the components before development of nanocomposite. Surface modification has attracted strong attention owing to its ability to produce remarkable integration and an improved interface between the inorganic nanoparticles and the polymer matrix . Ultra sonication to improve dispersion seems to be the main step to remove agglomeriation. Debrupa Lahiri et al. [6] experimentally showed that mechanical properties are improved in Carbon fiber epoxy composites by addition of carbon nano filler. Such incoperation of carbon nano fillers into CF-epoxy composite have shown promising results in improving the mechanical properties, like, interlaminar fracture toughness (ILFT) , interlaminar shear strength (ILSS) , tensile strength and fatigue life. Indicating Nano fillers does truly have the potential to improve the properties. M. Venkatesan et al. [7] have investigated and analysis of glass fiber and CNT particles reinforced hybrid composites to wear behavior, shows that the decrease in wear rate was observed as the percentage of CNT filler particles increases. B. Qi, et al. [8] has investigated the effect of nano clay epoxy based composites. Different types of nano clay were used for this with the systematically distributed like Different tests were carried out like fracture toughness, tensile strain, tensile strength and tensile modulus to investigated mechanical properties. From the results, it was observed that the enhancement in fracture toughness and elastic modulus. It also observed that the failure strain and failure strength was reduced while increasing the percentage of nano clay. From the former literature it was observed that adding filler materials to the composite can enhance the strength and properties of the composite material.

This work presents an investigation into fabrication and characterization of polymer composite materials reinforced with Graphene. With 4 different specimen of GFRP composite was created with varying percentage of graphine nano filler. And was tested for Tensile strength, Flexural strength, Interlaminar shear strength (ILSS).The research described in this undertaking was driven jointly by the needs for further improvement on the mechanical properties of polymer composite.

III. METHODOLOGY

The experiment is conducted in different stages. First stage involves procurement of material required which evolve both matrix and reinforcement materials and reaction agents. Then composite was fabricated using hand layup method to required ASTM standards. the final stage was the mechanical testing involved.

A. Materials

Graphine-embedded epoxy/glass fabric nano composites were chosen as the test material. Laminates were fabricated using the hand lay up process and employing an Sonicator for dispersion of nano filler with epoxy resin. Epoxy resin (LY556) and hardener (HY951) and E-glass fiber were used.

Table I Properties of grapheme-L

GRAPHINE-L	DESCRIPTION
Purity	99%
Thickness (Z)	5-10 nm
Surface area	60-200 m^2/g
Bulk density	0.45 g/cm^3
Odour	Odourless
Colour	Black powder

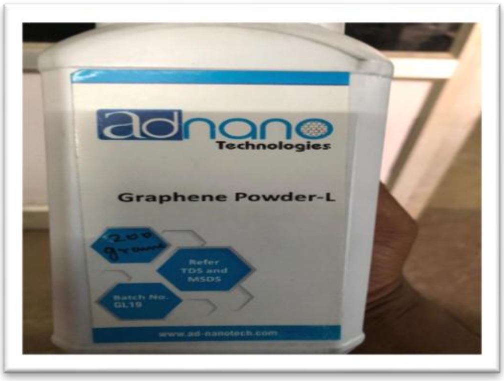

Fig 1: Graphene-L

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Fig 2: E-glass fiber

B. Composite preparation

For preparation of nanocomposites, Graphene Nano fillers are incorporated in to matrix in 0.5 %, 1 %, and 1.5 weight percentages. Graphene with were sonicated for 1 h at 20 kHz using ultrasonic vibrator to minimize agglomeration.. After allowing Graphene epoxy mixture to cool down to room temperature, so as to avoid premature curing, a low viscous curing agent Epoxy Hardener, was added and mixed using a mechanical stirrer rotated at 900 r/min for 5 min.

Fig 3: Fabrication process

Fig 4: Sonication

Finally, the mixture was applied on glass fiber sheet by hand layup technique. The vacuum bagging method was used to apply pressure for squeezing out extra resin at room temperature. Also a composite specimen was prepared with out Nano filler content. Each specimen was created on basics of Required ASTM standards for the tests.

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Table II Composite fabricated

	GRAPHENE NANO FILLER (WT %)	GLASS FIBER (WT %)	RESIN (Wt %)
SPECIMEN 1	0	30	70
SPECIMEN 2	0.5	29.5	70
SPECIMEN 3	1	29	70
SPECIMEN 4	1.5	28.5	70

C. Composite testing

After the fabrication process, composite tensile strength was measured by a universal testing machine with ASTM D3039 in cross head speed of 2 mm/min. In the same process, flexural test was performed by ASTM D790 with the same cross head speed. Interlaminar shear strength was found by short beam test with ASTM 2344 with cross head speed of 1 mm/min. With testing giving property values for tensile strength, Flexural strength, and interlamninar shear strength (ILSS) respectively.

III. RESULTS AND DISCUSSION

The tensile response of investigated composites is shown in fig 6. The addition of graphene filler in to composite seems directly influence the the overall tensile strength of the composite. The common GFRP with out any Nanofillers have the least amount of tensile strength of the four specimen produced with 110 Mpa.. The highest nano filler content seems to produce the highest tensile strength with 69.09 % increase from no filler content. From there with increase of Graphene content 21.5 % and 12.3 % increase is achieved from previous stage. The highest tensile strength was for 1.5 wt % of graphene which is 254 Mpa.

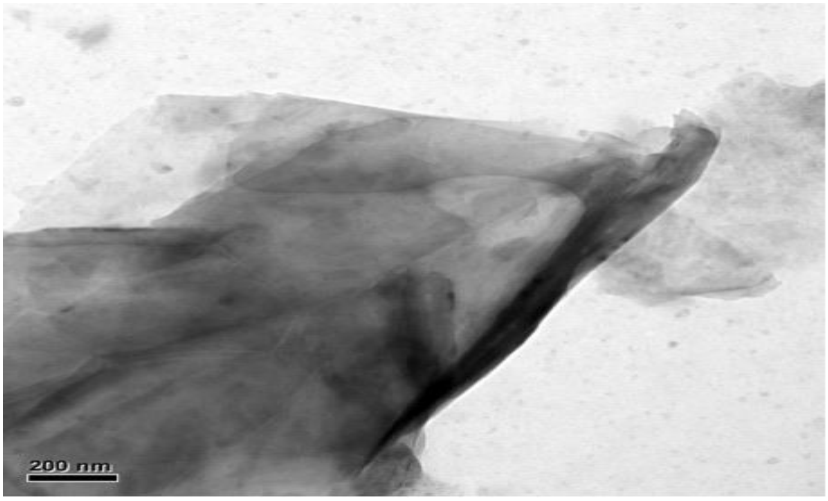

Fig 5: High-resolution transmission electron microscopy image of graphene-L

This definite increase of strength can be attributed to the high strength of graphene and increase in interfacial area due to high specific surface area of Graphene, resulting in better stress distribution for effective load transfer through the interface.

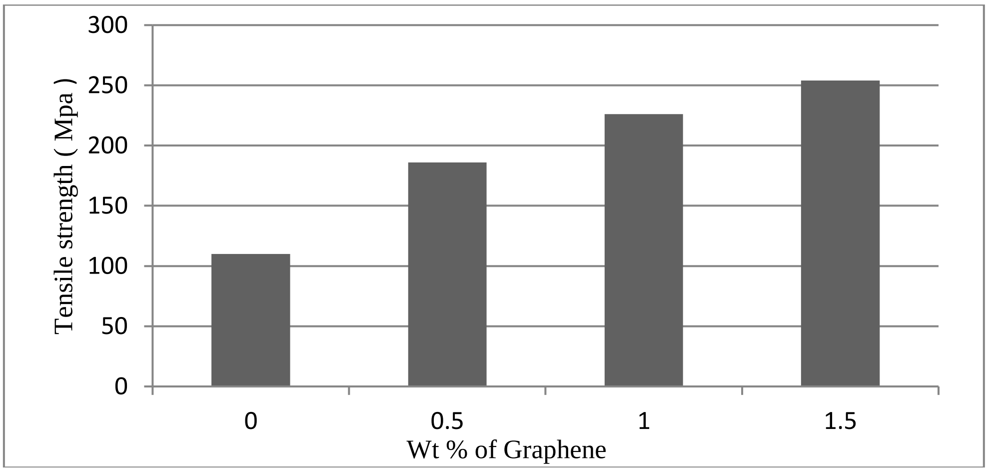

Fig 6: Tensile strength V/s Weight percentage of Graphene

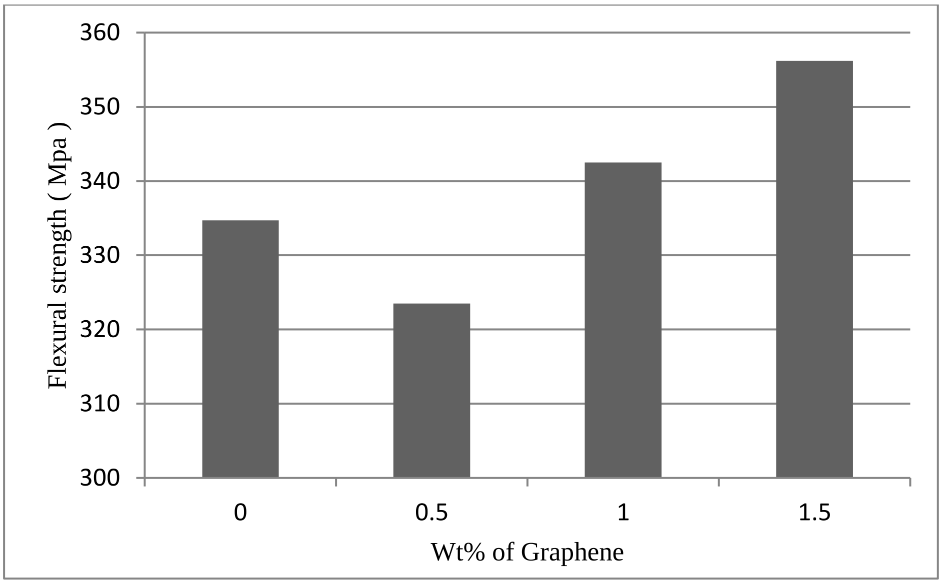

Fig 7: Flexural strength V/s Weight percentage of Graphene

For Flexural test The results shows initially there is a reduction in flexural strength value but with further addition of filler content can increase the strength value Fig 7. It depicts composite specimen with 1.5 % weight percentage graphene nano filer exhibiting a higher flexural strength 328.7 Mpa. 0.5 %, 1 %, exhibiting 323.4 Mpa, 325.9 Mpa respectively and no nano filler content only producing 323.4 Mpa. When the percentage weight of graphene added are beyond a certain limit i.e between 0 % and 0.5 %, these nano fillers agglomerate in a certain region of matrix causing non uniform transfer of stress along the composite laminates leading to a drop in the Flexural strength. Indicating agglomeration free filling is a necessary condition for certain increase in flexural strength.

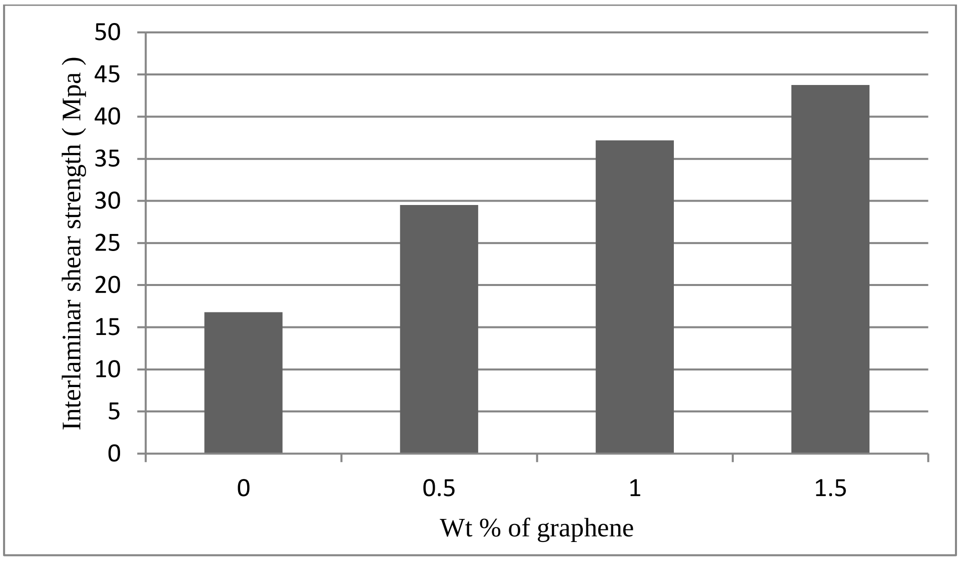

Fig 8: Interlaminar shear strength V/s Weight percentage of carbon

The interlaminar response of investigated composite is shown in Fig 8, where interlaminar shear strength of 1.5 % weight percentage graphene content composite seems to be highest. With 43.76 Mpa.. Increase in interfacial area and better load transfer seems to be the critical factor that seems to increase interlaminar shear strength, which is due to higher content of graphene Nano filler as reinforcement. When no filler content are added the ILSS seems to be the lowest with 16.8 Mpa. From strength increase to 29.53 Mpa, 37.20 Mpa, 43.76 Mpa respectively. And all these increase seems to be of positive trend.

IV. CONCLUSION

Graphene is potent in the effective reinforcement of Glass fibre reinforced polymer. Comprehensively its shown mechanical properties are clearly showing a positive trend. Tensile strength , Flexural strength, and more importantly interlaminar shear strength all seems to be increasing with addition of Graphene Nano fillers in to the composite matrix. And evidently its shown with increasing weight percentage of fillers the properties seems to be getting better. As with growing amount of filler content interfacial area for load transfer seems to be getting better also and better stress distribution seems to be achieving, which is the reason for the climb in properties compared to GFRP with out any Nano fillers. As Graphene itself is strong a material its interaction on composite matrix seems to be only positive. It could be understood Agglomeration of filler content on interface is a pivotal phenomena that need to be stopped during fabrication as its can have a adverse effect on the properties, as shown by the reduction of flexural strength going from 0 % to 1 % filler content. But overall it can be hypothesized that graphene has the capability to improve the strength of other fiber-based polymeric composites.

V. FUTURE SCOPE

The primary objective of this experiment was to indicate Graphene nano filler addition in to Glass fiber reinforced polymer composite would increase its mechanical properties and as its was a comprehensive success this work can be extended for performing drilling induced delamination study of GFRP with grapheme nano filler addition. Various delamination factors could be considered with analysis. Machine vision system could be implemented for the delamination analysis.

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