Studies on Mechanical Properties of Graphene based GFRP Laminates

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***Abstract*---Glass Fiber Reinforced Polymer (GFRP) is extensively employed in various applications for their improved properties. In order to improve the properties of the GFRP they can be combined with other material through the introduction of filler materials to obtain better properties. Development of advanced composites with improved properties is of utmost important, especially composite which are light in weight but with better tensile and flexural properties is the need of the hour. This dissertation work investigates the ability of Graphene powder to improve the mechanical properties of GFRP laminates. Investigations were carried out by adding graphene powder in different percentage to the GFRP and with different orientation of glass fibers. These composites were studied with respect to the mechanical properties. The effect of addition of graphene in GFRP laminates was investigated for their flexural and tensile properties. Addition of Graphene and orientations of glass fibers improved mechanical properties of GFRP composites.**

Keywords----Glass fiber GF), Graphene, Polymer Composite, Tensile test, 3- point bending test, Epoxy resin, Hand lay-up.

I. INTRODUCTION

In the present world the technology is being improved from decades. Even there is improvement and advancement in materials which are being produced for different application. When we look back, the conventional materials were being used in every application and due to the advancement in the material science the conventional materials are being replaced by composite materials. Where polymer composite materials are taking a vital role. They have excellent properties due to their excellent properties they are being used in many applications. They have many advantages like high strength ratio, they have low density when compared with the conventional materials and the most important is that the fabrication process is very simple and it is very easy.

Composites are highly preferred materials in aerospace, automotive and few consumer applications due to their better mechanical properties as compared to any others materials available in industry. These materials are highly preferred over conventional materials, since they can be customized based on the needs of a specific specific industry and this calls for material characterization. There are a number of standards available to characterized composite such as tensile test, flexural test. Polymers are particularly attractive as matrix materials because they can be easily processed and are able to provide better variation in density when compared to other materials. They exhibit excellent mechanical properties. High temperature resins are used as composite materials are currently used in the manufacture of high speed aircrafts, rockets and other relative space and electronics. The reinforcement share the major load especially when a composite consists of fiber reinforcement dispersed in a weak matrix. The fibers carry almost all the load. The strength and stiffness of such composites are, therefore, controlled by the strength and stiffness of constituent fibber. Graphene are superior high temperature materials with strength and stiffness properties maintainable at temperature up-to 2500 º K.

Fibrous material have poor conductivity in electricity when compared with the metallic components this is the drawback of fibrous material but they excel in resistance properties like resistance to heat, resistance to acid and resistance to alkali. To overcome this Xuqiang ji et al. [1] used graphene with the replacement of nanocarbon materials using graphene the properties improved where the conductivity increased, corrosion resistance was improved. Nicholas T. Kamar et al. [2] investigated the effect of graphene nano platelets on mechanical properties of glass reinforced composite in which the flexural strength of 0.25 wt % graphene nano plates was found to be high compared with other composites specimens of various wt % of graphene nano platelets. T.K. Bindu Sharmila, et al. [3] evaluated mechanical, thermal and dielectric properties of hybrid epoxy composites where Tensile strength impact strength and fracture toughness of GO / IO epoxy composite increased considerably. Improvement in mechanical properties was because of better polymer filler interaction and modifying crack propagation path. Dielectric properties such as dielectric constant and dielectric loss were increased with increase in GO / IO content within the epoxy matrix. Sanjay M R, et al. [4] reviewed mechanical properties of Natural – GFRP hybrid composites in which Addition of natural fibers in GFRP composite could be beneficial to improve mechanical and physical properties of composites. S. Channabasavaraju et al. [5] evaluated tensile and flexural property of PMC where Comparative study revealed that graphite fiber reinforced composite displayed high tensile strength compared with glass fiber reinforced composite, whereas exhibits less tensile strength than Kevlar fiber reinforced composite. Graphite fiber reinforced composite exhibits higher flexural strength as compared with both glass fiber and Kevlar fiber reinforced composites. The

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study was also displayed increase in thickness increases both tensile and flexural strength. ANSHIDA HANEEFA et al. [6] tensile test it was observed tensile strength and young's modulus increases with increase in volume fraction GF and SEM images revealed tensile failure is due to fiber pull-out. C.M. MANJUNATHA et al. [7] evaluated tensile fatigue behavior of GFRP using hybrid epoxy matrix. GFRP composite with hybrid epoxy matrix exhibits higher tensile strength compared with epoxy polymer composite. Chensong Dong et al. [8] evaluated flexural property of glass and carbon fiber reinforced epoxy composite. There was a decreasing trend for flexural properties with increase in percentage of GF. However positive results were observed for hybrid composite.

II. EXPERIMENTAL

A. Fabrication of Laminate Specimen.

The GFRP laminates were fabricated using a bi-woven cloth material with same warp and weft sequence. The matrix material used in the preparation of laminated composites was epoxy resin LY556 and HY951 hardener along with DY021 araldite at room temperature in the ratio 10:1. A total of 3 samples were fabricated without graphene addition with different orientation of 30º, 60º and 90º for GFRP laminates. Addition to that by adding graphene to the matrix material in the percentage of 1, 2, 3 and 4% for each orientation of GFRP laminates and total of 12 samples were fabricated. The tensile specimen was of dog bone shaped specimens. The preparation involved placing one layer over the other and by applying the matrix material (epoxy resin) there by leading to the formation of laminates for GFRP. The glass of 320 gsm was selected to prepare the laminate. After the preparation the laminates were cured at room temperature for 24 hours. The overall length of the tensile test specimen is maintained at 165mm and width of 13mm with thickness of 3mm and the taper angle was 70 rad were prepared as per ASTM D638-02a, as show in the figure. The fabrication of specimen was done hand lay-up technique with vacuum technique for GFRP laminates.

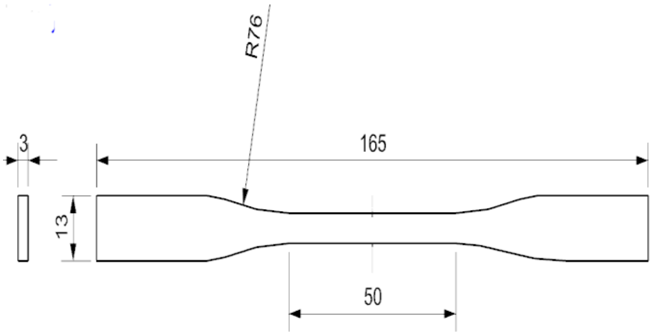

Fig 1: Laminate Tensile Test Dimensions – ASTM D638-02a

The flexural test specimen was fabricated using ASTM D790-2 with dimension are shown in figure 2 and the test setup is shown in figure 3. The standard dimensions included a spam length of 100mm between supports with a mid-point load at 70mm with cross head loading of 4mm / min. The flexural test specimens were fabricated in the similar way as the tensile test specimen. The specimen for both tensile and flexural test were fabricated in a panel form as shown in figure 4 and in turn were cut using a diamond saw which ensure no stress were created during the cutting process.

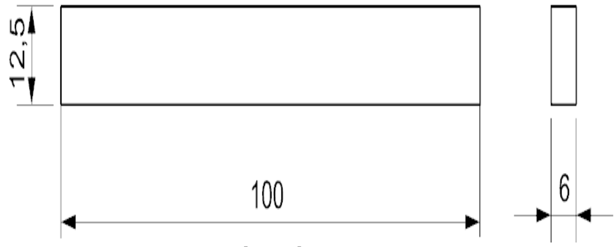

Fig 2: Laminate Flexural Test Specimen D790-2

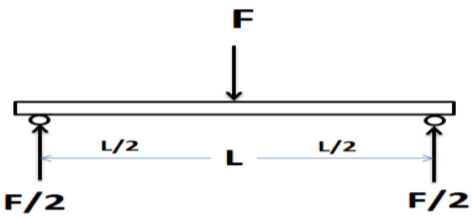

Fig 3: 3point (flexural) testing setup

Fig 4: GFRP Laminate Fabrication by Vacuum Bagging Technique

B. Tensile Test

Here dog bone shaped specimens are used for tensile testing. In any laminate, if the tensile force is along the fiber direction it is assumed to have higher axial strength. The overall length of the tensile test specimen is maintained at 165mm and width of 13mm with thickness of 3mm and the taper angle was 70 rad. As shown in figure 1. The tensile test specimen of GFRP as shown in figure 4. The tensile specimen was held in a universal testing machine by wedge action grips as show in figure 5 and pulled at recommended cross head speed of 4mm/min which corresponds to a strain rate of 0.2%/sec

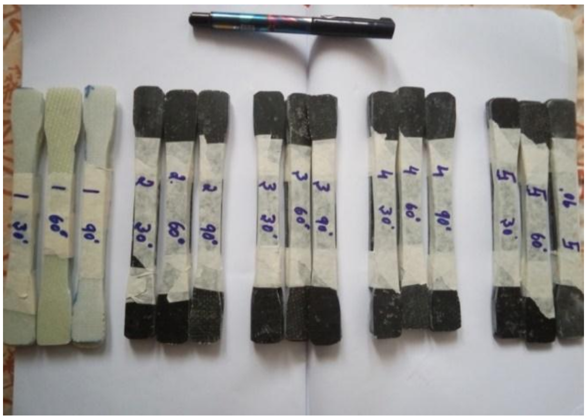

Fig 4: Tensile Test GFRP laminates

Fig 5: UTM (Tensile Testing)

C. Flexural Test

A total of 15 specimens with dimension of 100×13×3mm were fabricated. The GFRP Flexural test laminates were cut from panel using diamond saw, to ensure that no stresses are induced into the laminates, there by not affecting the flexural test properties. The laminates are prepared as per ASTM standards D 790 a flexural test of central loading was provided with constant loading rate of 4mm/min. Few specimens were evaluated upto elastic limit and few until failure was encountered. Flexural testing setup is shown in figure 6.

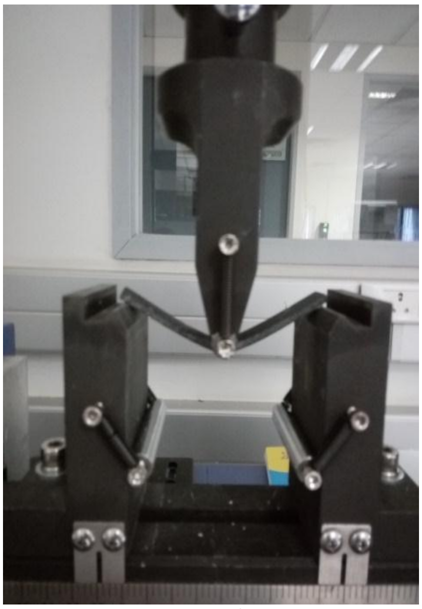

Fig 6: Flexural Testing of GFRP Laminates.

III. RESULS

A. Tensile Test

The tensile test was carried out on a Mecmesin – M i10 testing machine and the results of the test are tabulated in table I.

Table I: Tensile test GFRP Laminates

Sl No	Specimen No.	Percentage Elongation (%)	Peak Load (N)	UTS (N/mm^2)
1) Without Graphene	1-30-T	23.49	5145	127.68
	1-60-T	25.89	5885	146.03
	1-90-T	23.72	12307.80	365.63
2) 1% Graphene	2-30-T	21.04	5464	134.04
	2-60-T	25.25	6156	152.76
	2-90-T	22.25	12405.9	374.18
3) 2% Graphene	3-30-T	16.66	5702	141.48
	3-60-T	13.45	6258	161.44
	3-90-T	33.29	12862.6	392.42
4) 3% Graphene	4-30-T	11.93	7127	176.85
	4-60-T	24.55	7684	182.28
	4-90-T	21.80	13158.4	406
5) 4% Graphene	5-30-T	17.62	7454	192.46
	5-60-T	22.34	7875	214.34
	5-90-T	23.33	13590.3	428.18

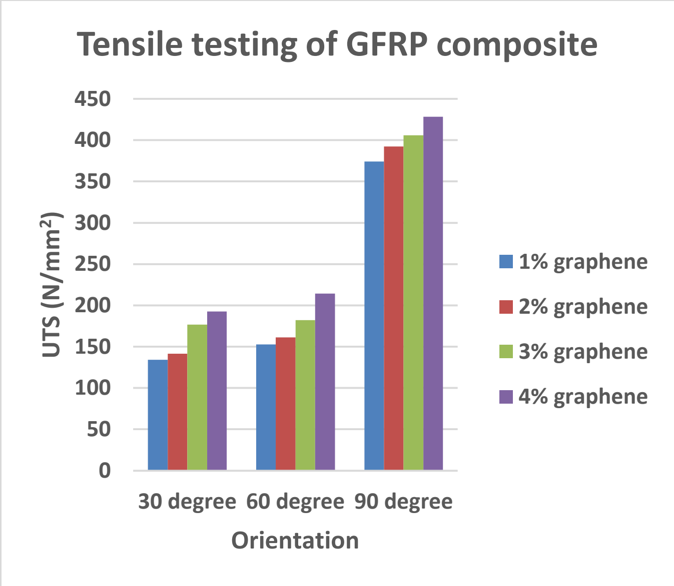

Fig 7: UTS Of GFRP Composites

The comparison is made on the basic of 2conditions. They are on the basis of orientation of glass fibber (30º, 60 º & 90 º) & on the basis of percentage of graphene added to it (without graphene, 1%, 2%, 3% and 4% graphene). In both the condition it was increasing linearly. Linearly from 30º orientation to 90º orientation also it was increasing linearly from without graphene to 4% graphene. Even it was found out that the tensile strength of 90º orientation was much higher when compared with both 60º & 30º orientation as shown in the figure 7

Fig 8.1: Fractured specimen after tensile testing of 30º orientation.

Fig 8.2: Fractured specimen after tensile testing of 60º orientation.

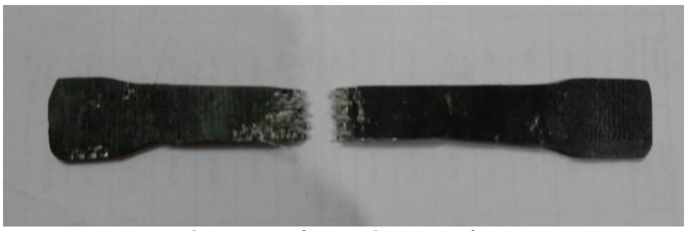

Fig 8.3: Fractured specimen after tensile testing of 90º orientation.

B. Flexural Test.

The flexural test was carried out on a Mecmesin – M i10 testing machine and the results of the test are tabulated in table II.

Table II: Flexural Test GFRP Laminates

Sl No	Specimen No.	Peak Load (N)	Max Displacement (mm)	Flexural Strength (N/mm²)
1) Without Graphene	1-30-F	183	28.20	4.73
	1-60-F	212	29.32	5.46
	1-90-F	297	17.24	7.66
2) 1% Graphene	2-30-F	279	33.95	7.20
	2-60-F	295	27.85	7.63
	2-90-F	376	18.63	9.70
3) 2% Graphene	3-30-F	300	33.19	7.73
	3-60-F	340	33.622	8.20
	3-90-F	394	24.54	10.43
4) 3% Graphene	4-30-F	333	29.57	8.58
	4-60-F	370	30.62	9.60
	4-90-F	410	20.38	11.05
5) 4% Graphene	5-30-F	394	32.26	9.74
	5-60-F	403	32.5	10.50
	5-90-F	452	23.33	11.66

It was found from the table II that flexural strength is Linearly from 30º orientation to 90º orientations also it was increasing linearly from without graphene to 4% graphene. Even it was found out that the flexural strength of 90º orientation was much higher when compared with both 60º & 30º orientation which is show in the figure 9.

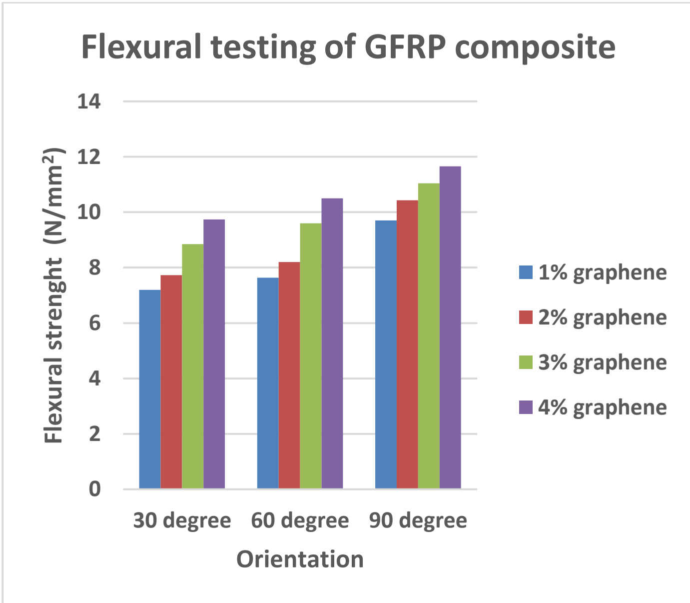

Fig 9: Flexural Strength of GFRP Laminates.

IV. CONCLUSION

In this chapter the conclusions are made by the result obtained by investigation of GFRP composite. Investigations are carried out by tensile & flexural testing.

- From tensile test investigation, it was found that the Tensile strength increases with the increase in the percentage of graphene added to the GFRP laminates, it increases linearly from 1% to 4%
- It was also found out that the tensile strength of 60º orientation of glass fiber is higher than that of 30º orientation & the tensile strength of 90º orientation is much more higher than that of 60º orientation. So 90º orientation was found out with high tensile strength and which is virtuous.
- Three point bending test results showed that Flexural strength increased with the percentage of added graphene increased from 1% to 4% graphene to the GFRP laminates.
- Also the flexural strength increased 30º to 60º to 90º orientation.
- This dissertation work investigates the ability of Graphene powder to improve the mechanical properties of GFRP laminates.

Finally it was found that with the addition of graphene the tensile & flexural strength of the GFRP laminate were increased with the increasing percentage of graphene in the laminates of GFRP.

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