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Study of flexural strength and moisture absorption of graphene reinforced polymer composites

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Abstract: -- Fiber reinforced composites have been gaining wide use in variety of application. The glass fibre reinforced hybrid composites were prepared by varying the weight percentage of graphene by 2%, 4% and 6% using vacuum bagging technique. The mechanical properties such as Flexural Strength and Flexural Modulus were studied. Moisture absorption into glass-epoxy and glass-epoxy-graphene composites immersed in -20oC and 100oC in water for 6 hrs was investigated and effect of addition of filler in glass fiber reinforced polymer (GFRP) laminates were studied. It was observed that flexural strength and flexural modulus increases linearly with increase in graphene content as compared with glass-epoxy composites. Moisture absorption test showed that in cold condition at 2% addition of graphene increased water absorption compared to 4% and 6%.When it is subjected to hot condition water absorption is increased linearly with increase in graphene %.

Keywords: Graphene, GFRP, Vacuum bagging technique.

1. INTRODUCTION

Composite laminate is a combination of fiber and resin mixed in proper form. One of the unique properties of composite laminate is that it has high specific strength. Composites are being utilized as viable alternatives to metallic materials in structures where weight is a major consideration, e.g., aerospace structures, high speed boats and trains. The concept of composite materials is that to combine variety of materials to produce a new material with excellent properties by the individual constituents.

Hybrid Polymer Composites (HPC) are one of the recent developments to reduce the cost of expensive composites containing reinforcements like carbon fiber by incorporating a proportion of cheaper, low-quality fibers such as glass, textile, natural fibers etc. and fillers like Multi walled carbon nanotubes (MWCNT) and graphene, without reducing the mechanical properties of the original composite.

Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fibre reinforced composites. Normally it contains a high modulus fibre with low modulus fibre. The high-modulus fibre provides the stiffness and load bearing qualities, whereas the low-modulus fibre makes the composite more damage tolerant and keeps the material cost low.

Generally, composite materials contain matrix and filler/ reinforcement. Matrix holds the filler together to form the bulk of the material and is of various forms like metals, ceramics and polymers. Filler is the material that is stronger than the matrix and when introduced to the matrix, provides strength to the composite. These fillers can be of any forms like fibers, glass bead, sand, ceramic, whiskers etc.

Xin wang, et al. studied the effect of graphene in combination with flame retardants on mechanical and flammability properties of GFRP composites. The composites samples with varying graphene percentage were prepared by hand layup method. Thermal analysis revealed that presence of flame retardants decreased the glass transition temperature it also observed that mechanical properties such flexural modulus, impact modulus and tensile strength decreased at an acceptable limit [1].

PatilDeogonda, et al. developed new polymer composites consisting of glass fibre reinforcement, epoxy resin and filler materials such as Titanium dioxide (TiO2) and Zinc sulphide (ZnS). Experiments like tensile test, three point bending and impact test were conducted and it was found the significant influence of filler material on mechanical characteristics of GFRP composites [2].

Satnam Singh, et al. studied on mechanical properties of pure epoxy and glass fibre (mat) reinforced epoxy at 10% and 20% weight fractions of glass fibres. The experimental results revealed that with increase in weight fraction of reinforcement, the tensile strength and flexural strength increased by 14.5 % and 123.65% for 20 % glass reinforced composites over pure epoxy[3].

T D Jagannatha, et al. Glass/Carbon fibre/Epoxy based hybrid composites were developed using vacuum bag process by varying both the reinforcements in terms of weight percentage of 15%, 30%, 45% and 60% of glass fibre. The inclusion of carbon fibre mat reinforced polymeric composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite [4].

P.S. Shivakumar Gowda, et al. in his work the graphene (0.2wt%) is mixed with glass fibre, carbon fibre , epoxy and specimen fabricated by hand layup. 0.2 wt% Graphene show that there is an increase in modulus of elasticity by 10 to 15%. Similarly the flexural strength decreases by adding Gr fillers [5].

A review of literature shows that very few information available regarding hybrid composites. Here an attempt is made to study the mechanical properties of glass fibre reinforced hybrid composites using graphene as filler material by varying the weight percentage of graphene by 2%, 4% and 6% and using vacuum bagging method to fabricate specimen. The mechanical properties such as Flexural Strength, Flexural Modulus and Moisture absorption were studied and effect of addition of filler in GFRP laminates are investigated.

2. MATERIALS

The hand layup method was used to prepare the composite materials. The GFRP laminates were fabricated using a bi-woven cloth Material. The Glass Fiber mat selected was, Mat 300GSM. The filler materials graphene were added 2, 4 & 6 %. The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6)) in the ratio 10:1, both manufactured by ATUL India Ltd, Gujarat, India.
The volume fraction were calculated for 60-40 (60% Glass Fiber – 40% Epoxy Resin).The three test samples were prepared with and without graphene addition for GFRP laminates.

Sl No	Glass Fiber%	Epoxy %	Graphene %
1	60	40	-
2	60	39.2	0.8
3	60	38.4	1.6
4	60	37.6	2.4

Table 1 Composition for preparation of composite laminates

3. EXPERIMENTAL DETAILS

3.1 Composite Preparation: Hand Lay-Up technique was used for the preparation of the polymer matrix composite and the steps followed as

Step1: Initially the flat surface is cleaned by acetone and releasing agent is applied on the mould (to ensure smooth removal of the laminate from the mould & to avoid its adhesion to the mould).

Step2: The required amount of matrix material is weighed and poured in the glass beaker and hardener is added in the ratio 10:1 are mixed by using mechanical stirrer. (It is a process used to mix hardener with epoxy- nanoparticle mixture uniformly through. The speed of rotor of mechanical stirring will be set around 250 rpm and the process is carried out for 5minutes in an ice bath to avoid increase in temperature/lower the heat generated during the mixing of the resin and hardener mixture)

Step3: The glass of 300 GSM (The bi-woven cloths of thickness 0.25 mm is taken , later according to the required size and shape the bi-woven cloths are cut) was selected to prepare the laminate are placed on a flat surface

Step4: The glass fibers are placed one layer over the other (The cloths of 7 layers are taken and placed one above the other to form layers such that the thickness of 2mm.) and epoxy resin is applied.

Step5: The GFRP laminates were prepared by vacuum technique (Vacuuming is done to remove the air traps between the layers)

Step6: The prepared laminates were cured at room temperature for 4 hours.

Step7: Then material is post cured at temperature of 60oC in the furnace for 2 hours

Step8: The cured materials are cut into required size & shape as per ASTM standards.

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Step9: The specimens are tested to study the Flexural Strength, Flexural Modulus and Moisture absorption of GFRP laminates.

3.2 Laminates Thickness Measurements

The thickness of prepared laminate plate were verified at six different points using Digital Micrometer and it is shown in table 2. Measured results shows that the 2mm laminates is achieved at different % of graphene.

% of Graphene	P 1	P 2	P 3	P 4	P 5	P 6	Avg (mm)
0%	2.0570	1.9580	1.9120	2.0140	2.0740	1.9610	1.9960
2%	2.0690	2.0850	2.1250	2.0030	2.0870	2.1080	2.0790
4%	2.0060	1.9850	2.0110	1.9550	1.9240	1.9970	1.9790
6%	2.0790	2.0700	2.0480	2.0790	2.1850	2.1750	2.1060

Table 2 Measurements of laminates thickness

3.3 Flexural Strength and Flexural Modulus

Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. The flexural test specimen was fabricated as per ASTM D7264.The composite samples are subjected to three-point bend tests as shown in figure 1. The bench tensometer with a displacement rate of 5.0 mm/min was employed to perform the tests (It is usually a universal testing machine loaded with a sample between two grips that are either adjusted manually or automatically to apply force to the specimen. This machine works either by driving a screw or by hydraulic ram).The three specimens of each composition were tested.

The flexural strength (σF) was determined using the following equation σF =3FL/bh2

The flexural modulus was determined using the following equation EF =L3m/4bd3

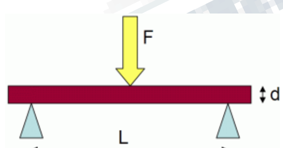

Figure 1 Three-point bend test

3.4 Moisture Absorption

The composite specimens used for moisture absorption test were immersed in a water bath at hot and cold temperature for 6 hrs. The specimens were taken out from the water and wiped with filter paper to remove surface water and weighed with digital scale. The percentage of the water content (Mt) was determined using the following equation Mt= (Wf - Wi/Wi) x 100

4 RESULTS AND DISCUSSIONS

4.1 Flexural Test

The flexural strength for various composites are shown in table 3. The flexural strength of the composites varies from 150 MPa to 360 MPa and the maximum value is obtained for composite with 6% of graphene. The flexural strength increases linearly with increases in % of graphene due distribution of filler material in the epoxy matrix. The flexural modulus varies from 45.43 GPa to 77.50 GPa and it is maximum at 6% of graphene.

Sl No	% of graphene	Flexural strength (MPa)	Flexural Modulus (GPa)
1	0%	151.153	45.43467
2	2%	249.028	65.69307
3	4%	331.861	70.54269
4	6%	362.115	77.50569

Table 3 Flexural strength and Flexural Modulus of composites

4.2 Moisture Absorption Test

The moisture absorption test at cold and boiling temperature for various composites shown in figure2. When material is subject to cold condition the water absorption is maximum at 2% of graphene composites. This is due to exposure of moisture causes degradation of the fiber matrix interface which causes significantly reduction in properties of composites. When material is subjected to hot condition water absorption increase linearly with increase in % of graphene and it is maximum at 6%.

This is due to better interfacial adhesion between the fiber and matrix.

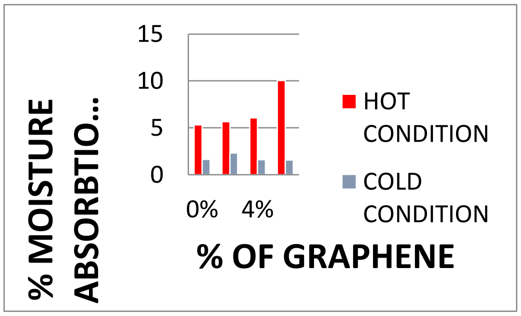

Figure 2 Moisture absorption at Hot and Cold Condition

5. CONCLUSION

1. Flexural strength and Flexural modulus increases with addition of filler material.

2. Graphene filled composite shows significantly good results than unfilled composites.

3. The glass epoxy composite itself is a brittle material and further addition of Graphene as filler made the material still harder and hence the bending strength increased with addition of filler content.

4. In cold condition the water absorption is maximum at 2% of graphene composites. This is due to exposure of moisture causes degradation of the fiber matrix interface
5. In hot condition water absorption increase linearly and it is maximum at 6%.This is due to better interfacial adhesion between the fiber and matrix.

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