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Mechanical Characterization of E-Glass Fibre Reinforced Composite with Graphene Nano Particles as Filler

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ABSTRACT

Graphene is one of the strongest materials that exhibit very good mechanical properties and can be utilized in many applications. In this paper, E-glass fibre reinforced composite is fabricated by adding graphene as nano filler in the weight proportions ranging from 1% to 4%. The tensile and flexural tests are performed in order to determine the elastic and bending strength of the material. Experimental results reveal that the presence of graphene in the composite for certain weight proportion increases the mechanical properties of the material. Also, graphene based E-glass fibre reinforced composite got better strength values than pure e-glass fibre reinforced composite.

Key words : graphene, E-glass fibre, epoxy, strength

1. INTRODUCTION

A new material can be developed with distinct properties by merging two or more materials of known characteristics. Such material is called as composite material. The composite material gains its own properties depending up on how best are the characteristics of the combining materials. Especially, mechanical properties of the new material are enhanced and always will differ from the properties of the blending materials.

A composite material will have a structure of two or more separable materials kept in contact using a binder and the excellency of its properties will depend up on proportions and orientations of the combining materials. One of the materials with highest composition is termed as matrix and the other materials of less proportion are termed as reinforcement. One such type of composite material is fibre reinforced polymer matrix composite which is used in several applications because of its good mechanical properties along with less manufacturing cost. Most frequently used fibre reinforcements are glass, carbon and aramid. They are made available in different forms to attain better reinforcement quality for the composite material. Another material can also be added along with matrix and reinforcement which is in very little proportion called filler and it should further improve the properties of the existing composite materials. Such composites are called multi scale composite materials.

Today industry requires materials with high strength and less weight. Glass fibre reinforced polymer is one of the reinforcement materials that can satisfy such need. It has twice the tensile strength of the steel and four times less in the weight. Also it is much cheaper than other fibre reinforced polymers. It is also having greater resistance for corrosion and chemical reactions which makes it as good choice for such applications. All these are achieved by glass fibre reinforced polymers because glass fibre is blended with thermosetting resins. Resins are binders for the glass fibre and are of three types. Polyester resins can be used easily because they are fast in curing and can with stand high temperatures. Epoxy resin is best choice for the composite manufacturers due to high strength and bonding capability with other materials. Vinyl ester resin is hybrid of above two resins.

Sometimes, more number of reinforcements can be blended in a single matrix; such materials are called hybrid composites. These composites are superior to normal composite materials and more advantageous in reducing its cost. Most preferably, carbon or glass reinforcements along with the filler material added in resin forms hybrid composite. Filler material should be in the solid form and also different in structure and composition of the matrix. Graphene is one such filler material in the form of nano particulates can be added in fibre reinforced composite material in order to enhance the mechanical properties. This is achieved by graphene because of its terrific blending ability with the matrix. Graphene based hybrid composites will have added advantage for emerging applications because there is exceptional improvement of properties made by fibre reinforced composites. Apart from enhanced mechanical strength graphene enables the composite to improve electrical properties even for a small portion of it added in the composite.

Sabapathi and Moorthy [1] has experimented glass fibre reinforced polymers by adding graphene in resin in weight ratios ranging from 2% to 10% in the steps of 2. It was found that there is increase in mechanical properties of the composite till graphene weight ratio is below 6% and got deteriorated with the increase of weight fractions of graphene. Supriya et. al. [2] has done a review on the graphene based carbon fibre hybrid composites and compared their properties with that of pure fibre reinforced composite. Graphene showed promising qualities that helped the composite to gain properties like mechanical, electrical and thermal. Zaheer et. al. [3] has studied the effect of the graphene nano platelets when added to epoxy matrix for varying weight proportions. The laminates are evaluated for the interlaminar shear strength and related the same with the mechanical strength for the given weight proportion of graphene and epoxy. Srivastava et. al. [4] has studied the flexural strength of the carbon fibre epoxy composites when coated with graphene nano platelets made by using vacuum assisted resin transfer moulding. It was concluded that the increase in oxidation time leads to decrease in the strength and elongation to failure. Umer [5] has investigated about the mechanical properties of the glass fabric composite combined with graphite nanoplatelets. With the addition of graphite nanoplatelets improved the strength of the composite due to impact and fracture. Papageorgiou et. al. [6] has reviewed the popularity of graphene based composites because of their enhanced mechanical properties like stiffness, strength and toughness. Hazim et. al. [7] has studied about the electrical and optical properties of poly-methylmethacrylate by mixing silver nano particles and found decrease of chemical hardness and increase of optical conductivity of the material.

The aim of this work is to identify the weight proportion of graphene that can be added in E-glass fibre reinforced composite in order to increase the mechanical properties of the material. Nano particles of the graphene are properly mixed in the epoxy resin in different weight proportions of which above 3% of graphene showed decrease in the strength.

2. MATERIALS AND METHODS

2.1 Materials

To prepare glass fibre reinforcement composite, epoxy and harder is mixed in 10:1 proportion and is used as matrix and E-glass fibre is used as the reinforcement. To make it a grapheme composite, graphene is added to the matrix in1% to 4% in the increment of 1%. The required materials are shown in Figure 1.

(a) (b) (c) (d)

Figure 1: Material procured to prepare composite (a) Resin (b) Harderner (c) E-glass fibre (d) graphene nano particles

2.2 Fabrication of Composite Laminates

In order to fabricate the composite laminates moulds are prepared using aluminium sheet for the dimensions of 200x200x5mm^3. Moulds are well designed for the easy removal of the laminates and must produce defect free specimens. The E-glass fibre is cut with the dimensions of 200x200 mm^2 and is placed in the matrix which is already poured in the mould. Matrix is a solution of epoxy and harder mixed in the proportion of 10:1. Graphene is also added in the matrix of epoxy and harder of proportions 1%, 2%, 3% and 4%. Alternate layers of matrix and E-glass fibres are placed till the thickness of the composite becomes 5mm. The fabricated composite material is shown in the Figure 2.

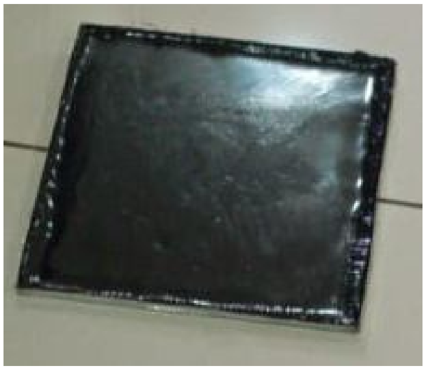

Figure 2: Graphene/E-glass fibre reinforced composite

2.3 Testing of Hybrid Composites

To find the mechanical properties of the fabricated composite the laminate is cut according to the standards. The tests conducted here are tensile test and flexural test.

2.3.1 Tensile Strength

The tensile strength of pure E-glass and graphene composites are obtained by conducting tensile test for the dog-bone specimens on universal testing machine. The specimen dimensions are taken per the ASTM D-638 standards and fabricated specimen is shown in Figures 3 and 4 respectively. The UTM with 25kN measuring capability is operated with cross head speed of 4mm/min at room temperature.

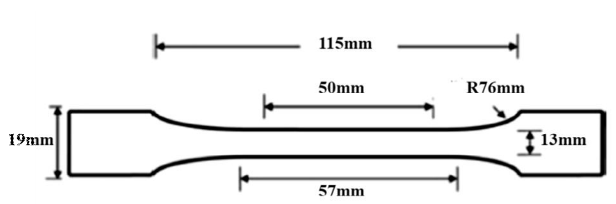

Figure 3: Tensile test specimen dimensions

Figure 4: Dog-bone specimen of the composite

2.3.2 Flexural Strength

Similar to the tensile test, flexural test is conducted on UTM for both the pure E-glass and graphene composite specimens to determine flexural strength. Along with the elasticity of the material its bending ability is also important. Figure 5 shows ASTM standard of D-790 that is followed in the preparation of the specimen (Figure 6) and a three point loading is performed to find the flexural strength.

3. RESULTS AND DISCUSSIONS

The results obtained from the tensile test and flexural test of the pure E-glass and graphene composites are mentioned here.

3.1 Tensile Strength

By increasing gradually applied tensile load along the longitudinal axis of the specimen, elastic properties of the material can be measured. A stress vs. strain diagram can be drawn till the failure point of the material. The curve obtained during the tensile test is very much useful in determining the mechanical properties of the composite material. The sample tensile test results for pure E-glass and 4% graphene composite are shown in Figures 7 and 8.

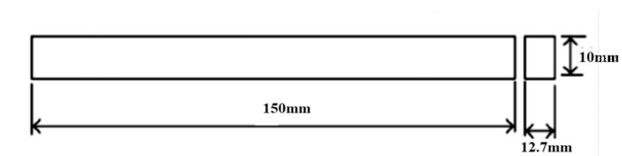

Figure 5: Flexural test specimen dimensions

Figure 6: Specimen of the composite

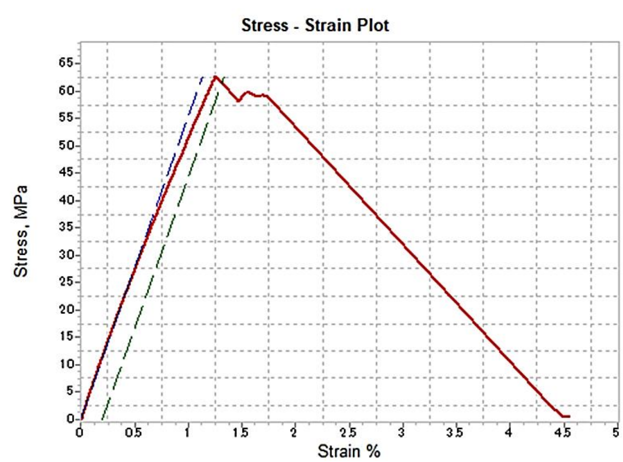

Figure 7: Stress-strain diagram of pure E-glass composite

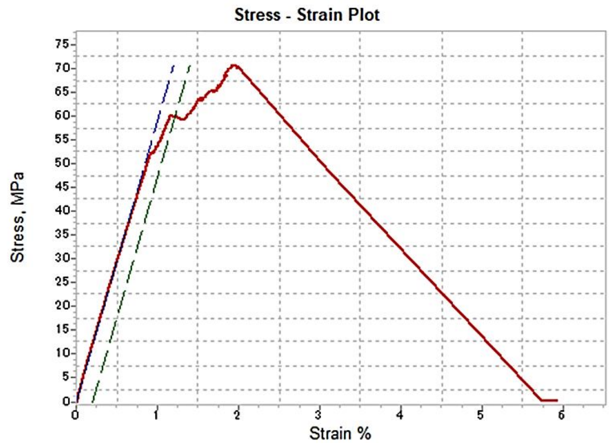

Figure 8: Stress-strain diagram of 4% graphene composite

Table 1: Tensile strength and percentage elongation of graphene composite

% of graphene	Ultimate tensile strength (MPa)	Peak Load (kN)	% elongation
Pure E-glass	62.67	2.82	4.58
1% graphene	69.43	3.12	5.02
2% graphene	74.37	3.34	5.37
3% graphene	77.55	3.49	5.61
4% graphene	70.65	3.18	5.11

The tensile strength and percentage elongation of the graphene composite material are given in table 1 and is clearly seen that the inclusion of the graphene has increased the elastic properties of the composite. The graphene have high tensile strength at 3% of its weight proportion in the E-glass fibre reinforced composite and further increase of graphene decreases the tensile strength.

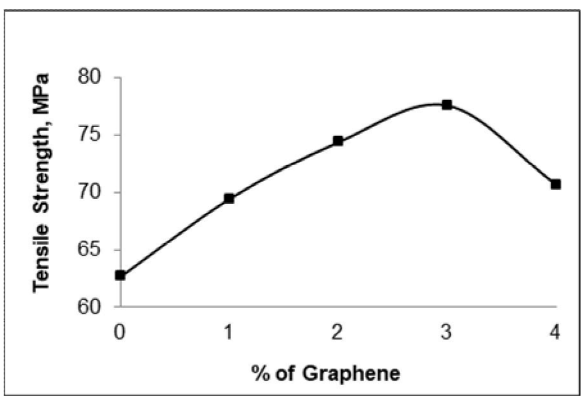

Figure 9: Tensile strength vs. graphene percentage

3.2 Flexural Strength

In order to determine the flexural strength of the material, three-point bending test is conducted. This strength is required for a material to withstand bending loads acting on it. The flexural strengths of the pure E-glass fibre reinforced composite and graphene composite are given in table 2 and the comparison is shown in Fig. 10. It is clearly seen that flexural strength increases with the increase in weight proportions of graphene till 3% and got depleted with further increase quantities of graphene.

Table 2: Flexural strength of graphene composite

% of graphene	Flexural strength (MPa)
Pure E-glass	42.29
1% graphene	57.94
2% graphene	71.07
3% graphene	80.66
4% graphene	64.49

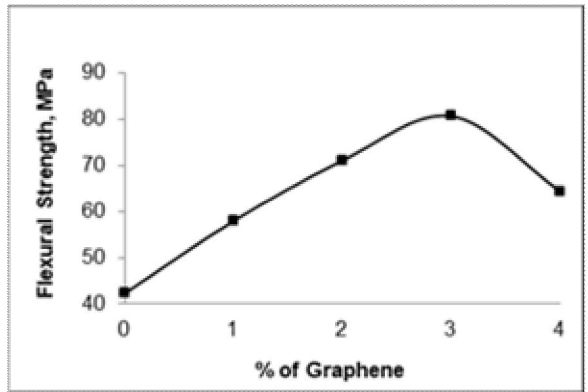

Figure 10: Flexural strength vs. graphene percentage

4. CONCLUSION

Composite materials are often added with filler material so that mechanical properties will further be increased and performs better than original material. E-glass fibre reinforced composite is fabricated with graphene nano particles added in the weight proportions of 1% to 4%. Experiments are conducted to determine tensile and flexural strengths of the new material. The results show that the brittleness of the E-gless fibre reinforced composite is reduced by adding the graphene into it. The tensile and flexural strength of the composite is increased till 3% of graphene added in the E-glass fibre reinforced composite and get decreased with the increase of weight proportions of the graphene.

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