# Influence of Graphene and Tungsten Carbide Reinforcement on Tensile and Flexural Strength of Glass Fibre Epoxy Composites

**Kalmeshwar Ullegaddi, C. R. Mahesha and Shivarudraiah**

**Abstract** Fibre-reinforced polymer composite materials show several superior properties over conventional engineering materials. Glass fibre has excellent mechanical properties. Hence, it is used as reinforcing agent to produce a very strong and relatively lightweight polymer composite. In order to enhance, the properties of glass fiber-reinforced polymer laminates by incorporating filler material to increase strength and mechanical properties. In this study, primary venture is to add up graphene and tungsten carbide filler into GFRP and study the behaviour of tensile, flexural strength. The composite was fabricated by hand lay-up process with sample thickness of 2.8 mm. It has been evaluated by the addition of 2, 4 and 6% of weight percentage graphene and tungsten carbide nanopowder filler material. The properties of the laminates will be tested by carrying out tensile and flexural strength per ASTM standard D 3039 and D 790, respectively. The effect of the addition of 2 wt% graphene will show the tremendous improvement in flexural strength, whereas addition 4 wt% of tungsten carbide shows excellent improvement in tensile strength compared with parent GFRP having an absence of filler material. It was observed that the GFRP reinforced with graphene and tungsten carbide improves the mechanical properties of GFRP.

## 1 Introduction

In the past few decades, composite materials have been focused more on the engineering and research world due to their superior performance-to-weight ratio compared

K. Ullegaddi (✉) · Shivarudraiah
Department of Mechanical Engineering, UVCE, Bengaluru 560001, India
e-mail: kalmesh.bdm@gmail.com

Shivarudraiah
e-mail: shivamechuvce@gmail.com

C. R. Mahesha
Department of Industrial Engineering and Management, Dr. AIT, Bengaluru 560056, India
e-mail: iemmahesh@gmail.com



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to conventional engineering materials [1]. With these superior performance characteristics, fibre-reinforced polymer (FRP) composites have seized the supermacy in the field of marine, aerospace, automobile and construction industries [2].

Glass fibre is by far the most predominant fibre used in the reinforced polymer industry and among the most versatile. In spite of the fact, the softening of glass and drawing in to fibers/long continuous fibers is ancient strategy, long continuous fiber drawn from the glass. Glass fibre-reinforced polymer (GFRP) is flattened into sheet form (chopped strand mat) or is in the form of woven thread into fabric. The glass fibre is made up of different types of glasses depending upon glass usage. Glass fibre consists of more than 50% of silica and varying fraction typical chemical composition of calcium, magnesium and oxide of calcium [3–5].

A glass fibre plays a very vital role in composites due to their low cost (Compared to Kevlar, Carbon) and possesses good mechanical properties [6]. In order to manufacture FRP, the resin becomes an important parameter. The resin material may be polymer, ceramic or metal. Epoxy is the one which is most used in FRP. The resin is in brittle nature characteristics and has low impact resistance. In order to enhance the properties of resin by adding micro or nanosized filler materials to attain desired properties [7].

Graphene is a new trending material due to its distinctive and excellent mechanical, electrical and thermal properties. At the other end, tungsten carbide is also considered as a better filler material for epoxy resins due to its useful family groups like hydroxyl and carboxyl [8, 9]. As a result of this, epoxy has excellent bonding with functional filler material (graphene and tungsten carbide).

## 2 Literature Review

Graphene nanoplatelets (GnPs), which have been recently developed as single-layered carbon nanomaterial, are a useful polymer reinforcement material which has a large surface area led to increasing the stress transfer between polymer and nanomaterial [10–12]. Graphene has a 2-D nanostructure and leads an enhancement in toughness of fibres. Several researchers reported that the graphene nanomaterial addition to the fibre-reinforced composites significantly affects the mechanical, dynamic, thermal and electrical [13, 14] properties of materials. Madhukar et al. [15] stated that GnPs inclusion in unidirectional composites significantly increased the interfacial adhesion and interlaminar shear strength as well as the flexural and tensile properties. Rafiee et. al. [16] carried out a details study on 0.125 wt% GnPs incorporation in the epoxy nanocomposite, results in the fracture energy increased about 115%.

Vacuum-assisted resin transfer moulding (VARTM) has demonstrated to be a powerful, low-cost method for the making of composite structures. Recent research on the effects of nanoparticles on resin penetration during the manufacture of composites by VARTM has centred primarily on carbon nanotubes, carbon nanofibres [17] and nanoclay. Very less information has been revealed about VARTM processing effects utilisation graphite nanoplatelets.

There are two essential strategies used to incorporating nanoparticles into FRP composites. One technique involves dispersing nanoparticles in the resin by stirring method [18–20], whereas the high surface region and aspect ratio of the nanofiller material can result in increment in the resin viscosity. More ever infiltration, aggregation of the nanoparticles can occur within the fiber tows of the composites [21, 22].

A second procedure is to coat the nanoparticles specifically onto the filament fibres [23] which eliminates the problems observed with the first technique. In this examination, the effects of exfoliated graphite nanoplatelets on the processing characteristics and mechanical properties of glass fabric composites fabricated by the VARTM process were explored.

It is foreseen that the addition of the nanoparticle filler material will enhance the out-of-plane properties of the composite including the interlaminar strength and fracture toughness and failure due to impact [24–26]. The higher surface area of exfoliated graphite nanoplatelets is one of the foremost characteristics of this sort of nanoparticles, which encourages creating a large interface zone in a nanocomposite [27].

The enhancement increment of nanoclay to glass fibre composite shows that an increase in interfacial shear strength and also reveals that the addition of nanoclay will drastically reduce the thermal expansion [28, 29]. However, an interface between fibres plays a vital role in an increase in the mechanical strength like tensile and flexural, and this would be achieved by the addition of nanofiller material into the resin epoxy, whereas the addition of nanofillers should be limited to 5 wt% rate to get better results in mechanical properties of glass fibre composites [30, 31].

B. Hao et al. revealed that glass fibre is coated with graphene oxide layer, results in more damage in interfacial fibre and poor in tensile and flexural strength. The author concludes that the addition of filler material does not depend on the improvement in mechanical properties, whereas the inclusion of nanofiller material plays a vital role [32].

## 3 Materials

In this present study, the S-Glass fibre material is selected for the fabrication of fiber-reinforced polymer composite where bidirectional woven S-glass fabric with 280 GSM is supplied by Marktech Composite Pvt. Ltd., Bangalore. It has unique advantages over E-glass fibres like high tensile and impact properties. The major constituent of fibre is silicon dioxide 64%, aluminium oxide 25 and 10% magnesium oxide. Epoxy LY556 resin is chosen as matrix due to having better adhesion and higher bonding strength. It has higher electrical insulation and chemical resistance properties. HY 951 hardener is used as a cross-linking agent with 10 wt% of fibres. Filler material graphene and tungsten carbide are used in this process to study the mechanical properties of composites.

## 4 Methodology

In this present research work, S-glass fibres are reinforced in the epoxy resin. The orientation of fibres plays vital role in end properties of composites. Placing the fibres in desired location and direction will produce better mechanical properties. In this study, we choose the fibre orientation (0°–90°).

The composite laminates are fabricated by hand lay-up process. A brush is used to apply resin on the surface of glass fibre. Glass fibre fabrics were cut into 300 × 300 mm cross section and placed in different directions (0° and 90°). Each ply of glass fibre fabric has a thickness of 0.22 mm. Hence, we consider 13 layers of glass fibre in order to make composite laminate of thickness 2.8–3.00 mm. Supply vacuum pressure to fibre mould, due to suction pressure layers gets accumulated to laminate and extra resin is sucked by the breather. Laminate left in a vacuum for 1 h to help layers adhere properly to one another. Laminate is cured at room temperature for one day and post-curing at 100 °C for 2 h. There are three types of laminates prepared such as without addition of filler material, with the addition of graphene (2, 4, 6%) and with the addition of tungsten carbide (2, 4, 6%) as shown in Table 1. Figures. 1, 2 and 3 show process view of the fabrication of laminates.

High precision water jet cutting machine is used to cut the laminates according to ASTM standards for further experimentation.

## 5 Experimental Study

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If any polymer composite material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result, engineers have developed a number of experimental techniques for mechanical testing of engineering materials


**Fig. 1** Stirring of filler material-reinforced epoxy resin

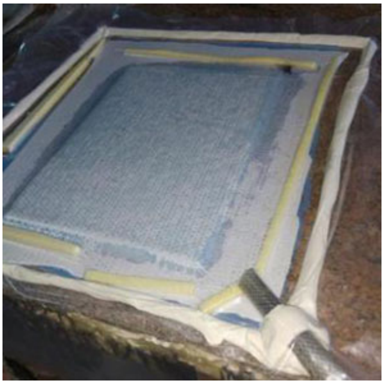

**Fig. 2** Vacuum pressure method to adhere to all layers effectively

**Fig. 3** Fabricated composite laminate

**Table 1** Composition details with sample code of laminates

| Composition | Epoxy wt% | Filler wt% |
|---|---|---|
| Glass-epoxy (G-E) | 40 | 0 |
| G-E + 2% WC | 38 | 2 |
| G-E + 4% WC | 36 | 4 |
| G-E + 6% WC | 34 | 6 |
| G-E + 2% Gr | 38 | 2 |
| G-E + 4% Gr | 36 | 4 |
| G-E + 6% Gr | 34 | 6 |

subjected to tension and bending. Test specimens are prepared with different weight fractions of filler material such as graphene and tungsten carbide.

## *5.1 Tensile Strength*

Often the material is subjected to forces and loads when they are used. The mechanical tensile test was conducted to measure the material strength when it is subjected to two opposite and equal forces applied. In this test, we found the percentage of elongation, ultimate tensile stress and elastic modulus. The tensile test specimen was prepared and cut into as per ASTM D-3039-76 having dimension of 250 × 25 × 3.0 mm [33]. The specimen is tested in a universal testing automated machine which is aided by Kalpak (100 kN) and loading rate of 1.5 mm/min at room temperature. Three samples were tested for each configuration composite material, and an average of three readings has been taken.

### 5.2 Flexural Strength

Flexural testing is coming under the destructive testing method, in order to find the amount of bending stress induced in the structure before its failure. Three-point bending method was adopted to test flexural specimen. The specimen is prepared according to the ASTM standard D-790 with dimension of 127 × 12.7 × 3.0 mm [34]. An experiment was conducted in the same UTM with the help of bending fixtures. In this case also, constant loading rate of 1.5 mm/min and three samples were tested for each composite configuration material. The specimens were subjected to loading to failure of the material.

## 6 Results and Discussions

### 6.1 Effect of Fibre Loading on Tensile Properties of Composites

The tensile strength of different function filler filled composites was decreased invariably with an increase in the irrespective of filler material. From Table 2, it is observed that the ultimate tensile strength (UTS) varies from 239.08 to 362.71 MPa. It is clearly shown in Fig. 4 that the ultimate tensile strength of the glass fibre is increased only when graphene content has been increased from 2 to 4 wt% and again it reduced to 6% wt of graphene. In the case of glass fibre reinforced with tungsten carbide, 4% wt of filler material shows remarkable tensile properties. In other end, % of elongation

**Table 2** Tensile test result of different proportion of filler material

| Composition | Filler % | % of elongation (mm) | Peak load (N) | UTS (MPa) |
|---|---|---|---|---|
| GFRP without filler | 0 | 3.15 | 16,736 | 239.08 |
| GFRP + graphene | 2 | 3.47 | 17,429 | 248.98 |
| | 4 | 3.64 | 19,369 | 276.70 |
| | 6 | 4.09 | 18,959 | 268.50 |
| GFRP + tungsten carbide | 2 | 3.42 | 20,059 | 286.56 |
| | 4 | 4.13 | 25,389 | 362.71 |
| | 6 | 3.16 | 18,897 | 267.22 |

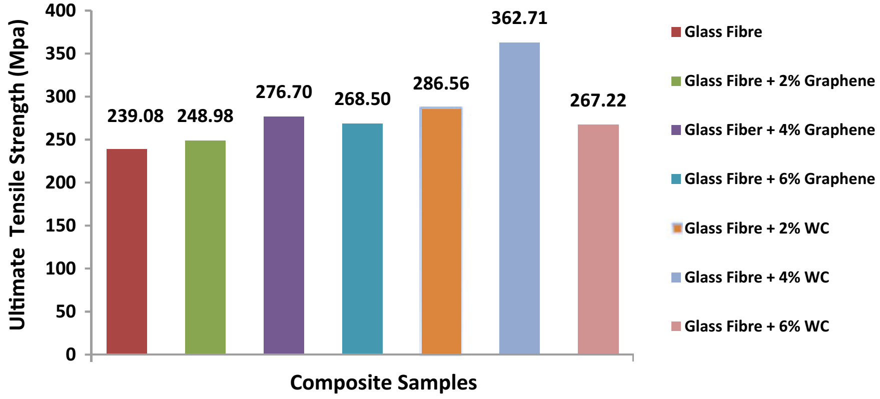


**Fig. 4** Ultimate tensile strength of GFRP composites

is directly proportional to peak load. The higher percentage elongation of composite takes place in glass fiber reinforced with 4 wt% of WC functional filler material that experiences a higher strength in composites as shown in Fig. 5. The reduction of strength of the composite may be by one reason, one chance is for pores in the filler material and matrix, and interfacial bonding may be weak to transfer the load. An increase in the addition of the higher weight percentage of functional filler material turns the glass fibre into more brittle in nature, and as a result, it reduces in the tensile properties.

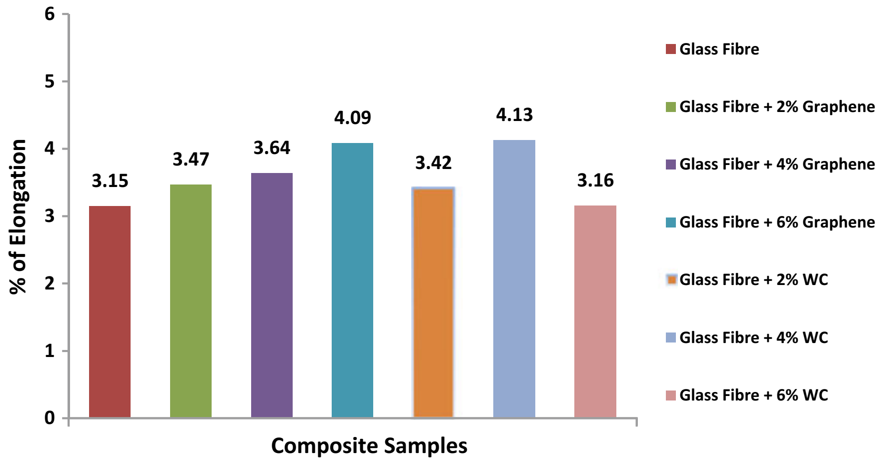


**Fig. 5** % of elongation in GFRP composites

### 6.2 Effect of Fibre Loading on Flexural Properties of Composites

The flexural property of a material can be increased by incorporating filler reinforcing in the matrix. The flexural property showed an interesting trend because each composite sample shows consistent pattern.

From Table 3, the value of flexural strength varies from 717.40 to 935.72 MPa.

Figure 6 clearly shows that the addition of 2 wt% of graphene has a significant rise in flexural strength when compared to other samples. Further addition of the higher percentage weight of functional filler material decreases the flexural strength of the composite structure. In case of tungsten carbide filler material, 4 wt% composition shows a better flexural strength and drastically reduced in strength with the other weight percentage of filler material. Decrease in flexural strength of composite with an increase in the weight percentage of functional filler material because of

**Table 3** Flexural test result of different proportions of filler material

| Composition | Filler % | Maximum displacement (mm) | Peak load (N) | Flexural Strength (MPa) |
|---|---|---|---|---|
| GFRP without filler | 0 | 13.71 | 625.37 | 717.40 |
| GFRP + graphene | 2 | 12.75 | 776.40 | 935.72 |
| | 4 | 12.34 | 693.98 | 836.40 |
| | 6 | 11.85 | 706.66 | 851.66 |
| GFRP + tungsten carbide | 2 | 12.95 | 651.31 | 784.97 |
| | 4 | 13.02 | 668.50 | 823.15 |
| | 6 | 12.51 | 631.66 | 742.03 |

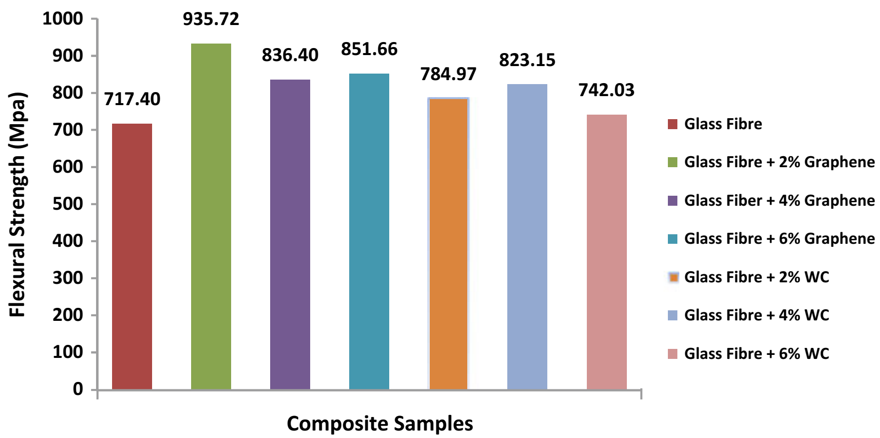


**Fig. 6** Flexural strength of GFRP composites

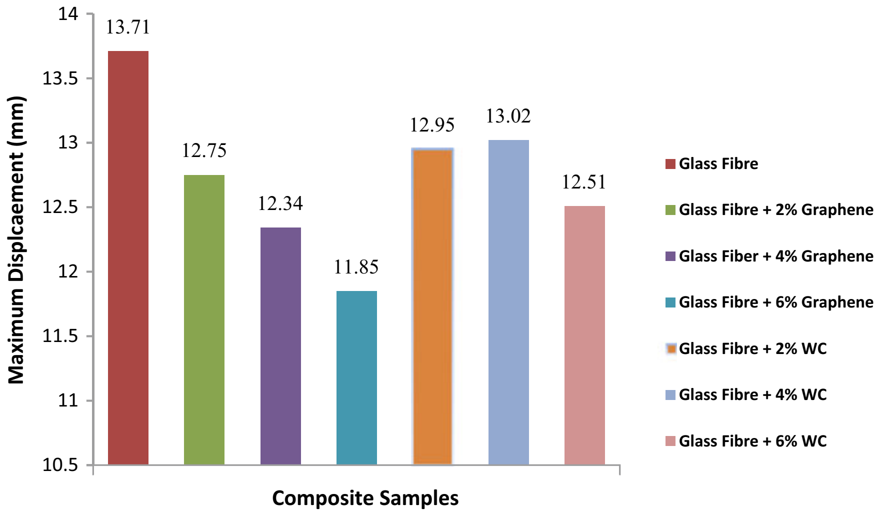


**Fig. 7** Maximum displacement of GFRP composites

its incompatibility of filler material and interfacial bonding between the matrix and reinforcement. From the Fig. 7, it's clearly reveals the maximum displacement occur in no filler filled glass epoxy composites, but as in the case of flexural strength 2 wt% of graphene experiences the higher strength results. However, it also depends on the size and shape of the filler material.

## 7 Conclusion

The conclusion of the study of S-glass fibre and graphene and tungsten-reinforced epoxy resin composite is that there is a significant increase in the tensile and flexural strength of the composite.

- Tensile strength improved by 51.70% by adding 4 wt% of tungsten carbide and increased by 15.73% gradually by incorporating graphene of 4 wt% loading of GFRP composites.
- Tensile strength is directly proportional to the % of elongation of composite, means more the % of elongation with more tensile strength.
- The flexural strength improved by 30.43% progressively with the 2 wt% of graphene and 14.71% by incorporating 4% of tungsten carbide filler material in composites subject to three-point bending loading condition.
- To increase the mechanical properties of the composites, there must be an appropriate amount of filler material and epoxy to fabricate composite laminates.

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