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Fabrication and analysis of mechanical properties of PVC/Glass fiber/graphene nano composite pipes

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Abstract

The aim of this work is to examine the conventional moulding method for manufacturing the PVC/Glass fiber/graphene nano composites. Uniform graphene dispersion is observed with the matrix for better bonding. The Mechanical properties of the manufactured nano composites have been done in this work. Three important standard tests were evaluated for the performance of Nano-Composites developed. The composites were developed as flat specimen for pipe applications. The three standards test which includes axial tension, compression and transverse compression is studied. The graphene nano composites were varied 0.5%, 1%, 1.5% and 2 percentages. Based on the results it can be concluded that the increase in the percentages of graphene made a uniform dispersion, which leads to increase in the compressive strength of the Nanocomposite. Increase in the axial compressive strength and stiffness was observed and the increase in the trend value is mainly observed in 1.5 wt% and 2 wt% respectively. The Graphene dispersion and fractured surface morphology of nano composites were examined using scanning electronic microscopy (SEM).It can also be used as an alternative for metal pipes in industries.

1. Introduction

The need of commodity polymers is increasing day by day due to its vast applications in various fields such as piping industry, automobile industry and packaging industries. For preparation of these composites various fillers and reinforcements were added additionally for its cost effectiveness and enhanced mechanical properties. In order to enhance the mechanical and thermal properties various nano materials have been added and studied with different composites. Glass fibers are widely used in various applications for its unified mechanical properties and enhanced strength [1, 2]. The Interventions of new reinforcement materials were used by researchers due to outstanding strength and its resilience with other composites [3]. Abot *et al* analysed the performance of the nano composites by using Carbon Nano Tubes (CNT) and concluded that the usage of Carbon Nano Tubes (CNT) in the matrix leads to the improvement in the mechanical properties of the composites [4]. In order for ease manufacturing of pipes steel was used as a potential material in industries. Though, steel has many advantages the corrosive property of steel is a major concern so that it cannot be used as a key engineered materials. Due to its disadvantages the steels were replaced by using some new hybrid composites. The epoxy graphene nano composites were used as an alternative for steel .It is identified that the combined effects of graphene with epoxy resin composites reduced the corrosive property of steel [5]. In order to improve the interfacial adhesion between the glass fiber and the matrix material Carbon Nano Tubes (CNT) was used as an additional ingredient by the researchers. Various studied have been carried out by the researchers for

Table 1. Description of all the materials used.

Sl.no	Materials used	Supplier details	Properties
1	Polyvinyl chloride	Steadfast Industries	Average density of 1.10 gram/cm^3
2	Graphene	Aljari Chemotech Ambattur	Diameter of 45 μm and a thickness of 7 nm
3	Glass fibers	Jeeva Natural Fibers Chennai	Smooth and fine Texture having length of 4.5 nm and diameter of 15 micro-metre silane treated.

improving the adhesive properties [6–8]. Many works have been carried out by using nano material agglomeration with the matrix. The nano filler composites with Carbon Nano Tubes (CNT) based composites were studied in various percentages such as 0.5 to 1 weight percentages.Karappase *et al* tried Glass fibers with Carbon Nano Tubes (CNT) as fillers and concluded that the improvement in the fracture energy was observed by using Carbon Nano Tubes (CNT) with carbon fibers. In another work the interfacial bonding strength between E-fibers and polypropylene was investigated by using Single wall Carbon Nano Tubes (CNT).They used in the application of sensors and concluded that the matrix with CNT can be utilized in sensor applications [9]. Though various works have been reported in the literature, by using various composites, The composite with PVC/Glass Fibers /graphene Nanocomposite were not studied so far and not explored. *Et al* performance of Graphene oxide by adding 0.5 weight percentage. Based on the evaluation he concluded that the Graphene oxide with epoxy enhanced the flexural strength of the developed composite [10]. Dines Kumar *et al* analyzed the mechanical performance of graphene oxide epoxy nano composites. He analyzed based on the in service temperature on stability interface. He concluded that the flexural strength increased at 80 to 90 degree Celsius [11]. Sen et al compared the mechanical performance of graphene oxide on short glass fiber polymer composites. He used extrusion compounding and injection moulding techniques to develop the composites. He concluded tensile strength got enhanced by using graphene oxide with glass fiber composites. Prust et al analysed the performance of the glass fiber composites. He analysed with epoxy resin and concluded that the graphene more than 0.5 percentages declined the flexural strength of the nano composites. This is mainly due to the agglomeration of graphene with glass fiber [12]. In various research works the agglomeration with the matrix have been done at various percentages from 0.2 to 0.5 percentages. In this for the purpose of agglomeration various mixing techniques have been used. Out of all the available blending techniques melt blending was identified as the best blending technique. The unified blending in the melted form is done for polyethylene composites in nano form with multi-wall carbon Nanotubes with addition of graphene nano sheets [13–15]. Thus the present work deals with the preparation of PVC/Glass Fibers/graphene Nanocomposite. Uniform graphene dispersion is observed with the matrix for better bonding. Various mechanical properties of the manufactured nano composites have been done in this work. Three important standard tests were evaluated for the developed specimen. The three standards test which includes axial tension, compression and transverse compression is studied. The graphene nano composites were varied 0.5%, 1%, 1.5% and 2 percentages.

2. Materials and methods

2.1 Composite pipe preparation

In this Research work the 3 main key materials such as Polyvinyl chloride/Graphene and Glass fibers were used for manufacturing the composites. Polyvinyl chloride was used as the matrix material which was procured from steadfast industries Chennai. Glass fibers and graphene were also used in this work and they were added as reinforcement.Synthesised graphene in the forms of sheets have been procured from aljarichemotech, Ambattur. The Detailed Description of all the materials used was discussed in the table 1. PVC, Glass Fibers and Graphene nano composite pipes were prepared in laboratory by using a melt mixing method by using twin screw extruder. The Functionalized graphene is used in this work and it was procured from Aljari Chemotech Ambattur having a Diameter of 45 μm and a thickness of 7 nm. Temperature of 230 degree Celsius is maintained for optimum time maintaining a screw speed of 250 rpm.PVC polymers having a density of 1.10 gm cm^{-3} was procured from steadfast industries. The bi directional woven glass fibers from 0 and 90 were used in this work. It was procured from Jeeva natural fibers Chennai. The composites were Prepared in a laboratory scale by using injection molding machine at an optimum pressure.In preparing these composites the graphene ratios were varied from 0.5 weight percentages to 2 weight percentages.For carrying out various mechanical tests the composites were cut into different shapes as per ASTM standards.The Details of all the Tests to be carried out is mentioned in the table 2.

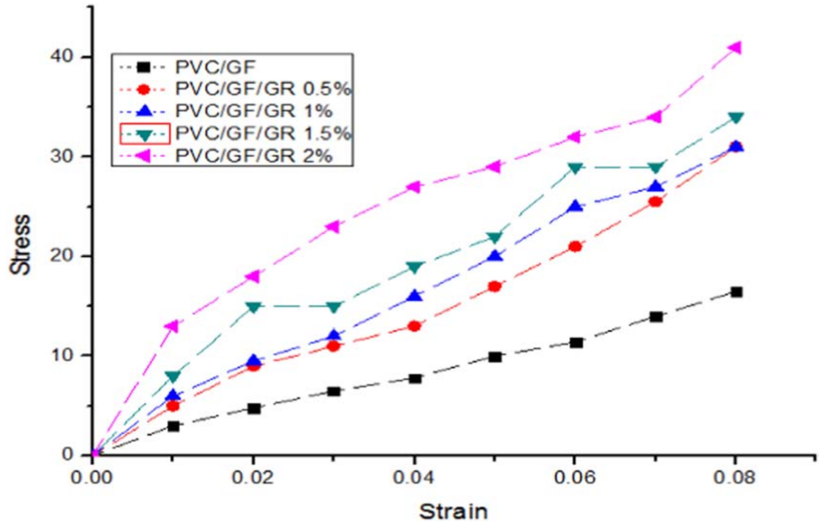

Figure 1. Stress Strain curve for the developed Nano-Composites.

Table 2. Test procedure and standards.

SL.NO	NAME OF THE TEST	STANDARD	PURPOSE
1	Axial Tensile Test	ASTM D3039	The test was carried out at room temperature and strain rate of 5 mm min^{-1} in the universal testing machine. The dog bone shape samples for tensile tests were cut using a saw cutter. The dog bone shaped samples were fixedbetween the grippers, and the load was applied until the failure occurs.
2.	Axial compression test	ASTM D1599	The test was carried out at room temperature to determine the compressive strength by using compressing testing machine. The Composites with an outer diameter of 50 mm and an inner diameter 45 mm with a length of 300 mm were prepared and subjected to compression.
3	Flexural Test	ASTM D790-10	The crosshead speed of the test was kept at 2 mm min^{-1} during the testing. During the testing process, the samples were subjected to load in the middle, and the values are noted until there is a fracture

2.2 Characterization of composites

The Prepared composites were characterized for various tests such as Axial Tensile Test,Axial compression test and Flexural Test were done. Nano composites were fabricated in the form of pipes. For carrying out various mechanical tests the composites were cut into different shapes as per ASTM standards. The Details of all the Tests to be carried out is mentioned in the table 2 [16–18].

3. Results and discussion

3.1 Axial tensile test

The test was carried out at room temperature and strain rate of 5 mm min^{-1} in the universal testing machine. The dog bone shape samples for tensile tests were cut using a saw cutter. The dog bone shaped samples were fixed between the grippers, and the load was applied until the failure occurs. The PVC/Glass fiber/Graphene nano composites with different weight percentages were prepared. The Changes in the variation of tensile strength with the addition of graphene dispersion is studied and it can be concluded that the tensile strength increases with the addition of graphene nano composites and the stress strain curve for the developed composites is shown in the figure 1. As seen in the figure 2,The highest tensile Strength was observed for the graphene with 2 weight percentages when compared to all the other composites, This is mainly due to the proper adhesion and interaction between the Graphene/Glass fiber and PVC composites. The other reason is attributed due to nano graphene dispersion with low agglomeration. The ultimate tensile strength of the composites is identified and it is presented in the below . As can be seen, as the weight percent of graphene increases, Ultimate tensile strength increased [17–19]. This is mainly due to the presence of high graphene percentages which leads to proper adhesion between the matrix and the composites. Therefore, using this method, one can take the advantage of

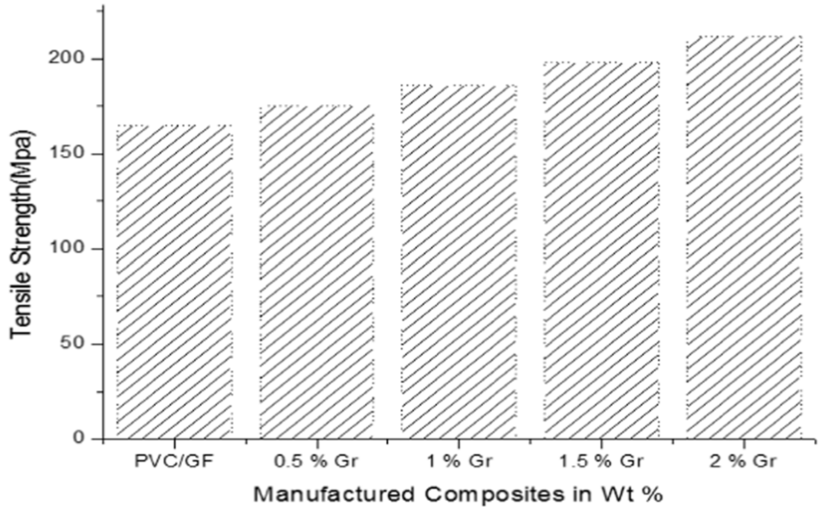

Figure 2. Tensile Strength of the developed Composites.

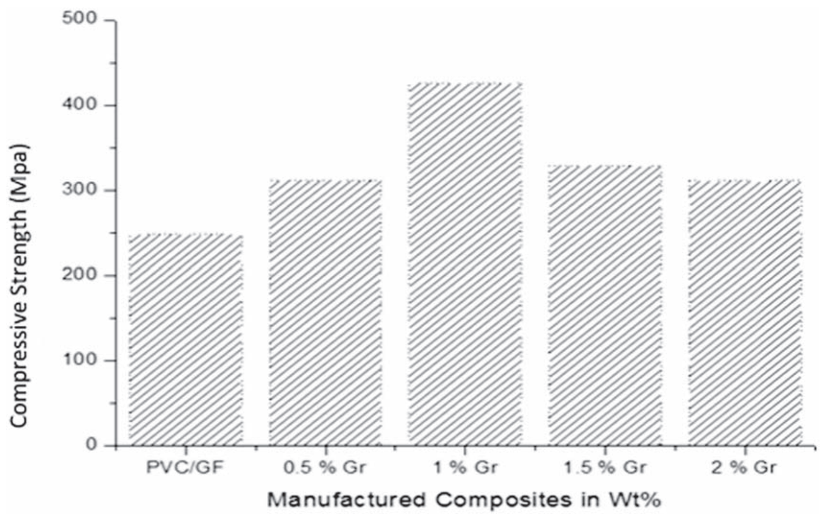

Figure 3. Axial Compression of the developed Composites.

the high potential of graphenes for mechanical reinforcement of Nano-composite. The increased strength of the fiber composites is due to the addition of graphenes, which improves the load transfer from the matrix and the fibers because of improved interfacial properties between the polymer matrix and the fibers. The same is in tandem with the literature [20–22].

3.2 Axial compression test

Axial Compression strength was measured and it is plotted in the figure 3.The test was carried out at room temperature to determine the compressive strength by using compressing testing machine. The Composites with an outer diameter of 50 mm and an inner diameter 45 mm with a length of 300 mm were prepared and subjected to compression. The maximum compressive strength of the developed composites was done by using the compression test as per ASTM D639-19 standard. The composites were prepared and subjected to axial compression. Based on the results it can be concluded increasing the graphene content increased the maximum compressive strength of the nano composites but after adding above 1 percentage of graphene the value starts deteriorating. The composites having 0.5 weight percentages of graphene had 323.4 Mpa as the compressive strength and 1 weight percentages had 425.6 Mpa later the value started to decrease. This may be due to the improper dispersion of the particles [19].

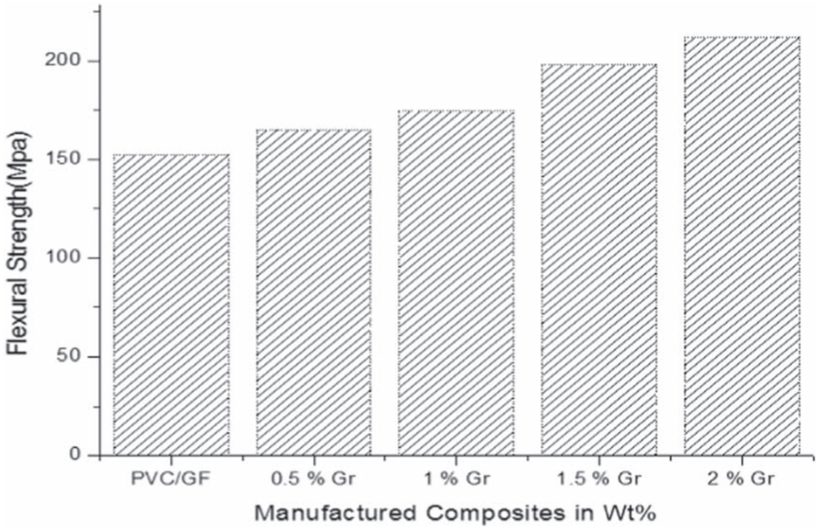

Figure 4. Flexural Strength of the developed Composites.

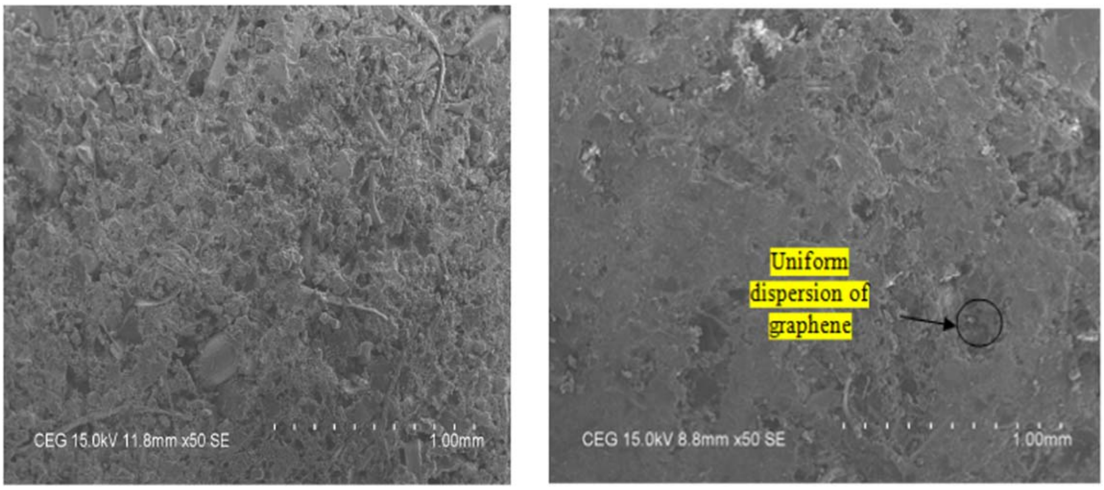

Figure 5. Dispersion of Graphene in the developed Composites(1.5 wt% and 2 wt%).

3.3 Flexural test of the developed composites

The Flexural Strength of the developed composites is shown in the figure 4 and it does not follow an increasing trend The Flexural Strength fluctuation was observed in the composites developed. The 2 weight percentages of Graphene/PVC/Glass fiber decreased drastically. This may be attributed due to poor interfacial bonding and fiber pullouts [23]. By seeing this trend it can be observed that the 0.5 to 2 weight percentages of graphene composites provided an enhanced incremental failure. The same trend was observed and reported in the literature between the matrix and the fiber at the low addition of graphene composites. The optimal concentrations of graphene composites addition were observed and it was concluded and it was observed that the same trend was observed as tension for the flexural developed composites [20–22, 24, 25].

3.4 Scanning electron microscopy analysis of composites

The SEM micrographs of the developed composites for the developed PVC/Glass fibers and Graphene composites are shown below in the figure 5. The smaller nano graphene in the composites with less larger agglomerates were observed in the developed PVC/Glass fibers and Graphene composites [26]. Based on the results it was observed that the decreasing trend in the agglomeration was observed due to increase in the highest weight percentages of graphenes. The higher portion of graphene increases the mechanical reinforcements of all the composites. The increased in tensile strength is observed due to the presence of graphenes which improves the load transfer between the fibers and the matrix. The Interfacial properties improved the load transfer between the polymer matrix and the fibers.In fact, the presence of graphenes creates a bridge between the fibers and the polymer matrix, causing

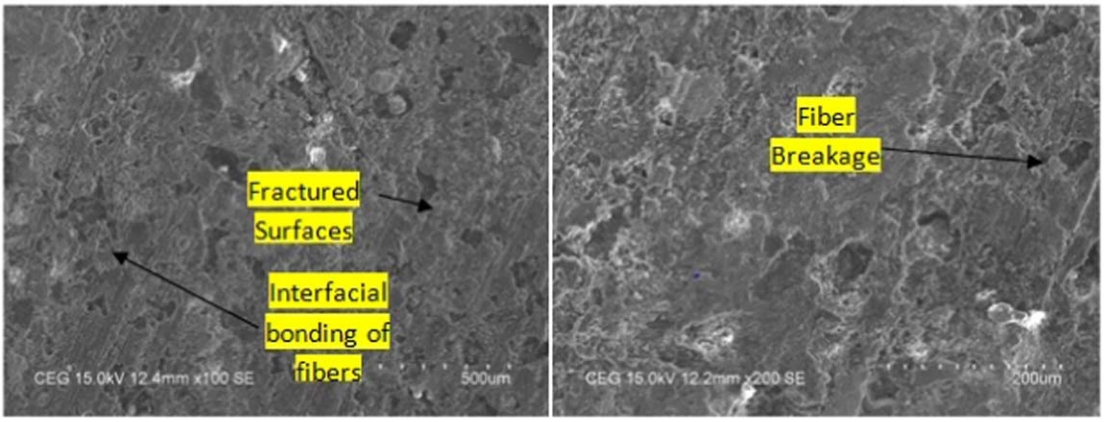

Figure 6. (a) Fractured Surfaces of the PVC/GF/Graphene Composites. (b) PVC/GF/Graphene 2wt%.

them to lock and engage with the glass fibers and PVC.The graphene percentages inclusion with PVC increased the overall adhesive property of the matrix and uniform dispersion was observed with the matrix.By seeing the figure bit can be observed that the load transfer was observed and the proper bonding between the matrix and fibers were observed in the figures 6(a) and (b). However increasing the adhesive property of the fibers with the graphene at 2 weight percentages the fiber breakage was observed [27–29].

4. Conclusions

The present study reported the fabrication method and influence of Graphene content on the mechanical properties of PVC/Graphene/Glass Fiber composites. The experimental results recommended that mechanical properties of the composites were enhanced with the graphene dispersion and the improvements in the fiber matrix were observed damage mechanisms and interfacial bonding and debonding properties were analyzed by using sem. Based on the results the conclusions are provided below.A PVC/GF/Graphene nano composite has been fabricated by injection molding method and its mechanical properties have been evaluated. Based on the results it can be concluded that the proper blending of graphenes with the polymer is observed. The combination of PVC/Glass fiber/Graphene Composites enhanced the mechanical strength of the developed composites. PVC/Glass fiber composite, the matrix phase is strengthened, and the adhesion between the polymer and the fibers is improved. Increase in the axial compressive strength and stiffness was observed and the increase in the trend value is mainly observed in 1.5 wt% and 2 wt% respectively.

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