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Investigating the Functionality of Graphene Fiber Reinforced Plastic (GFRP) Laminates

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Abstract

The increased adaptability and usefulness of glass-fiber reinforced polymer has led to its widespread adoption. GFRP laminates can be improved by including filler materials to improve their already impressive set of qualities. The demand for the research and development of advanced composites with enhanced properties has never been greater, and this is especially true for composites that are lightweight but have enhanced tensile and flexural qualities. An example of a laminate lay-up is one in which the lamina plies are stacked at acute angles to one another. Laminates made from continuous fibers are often arranged so that their strength is maximized along the direction of most major stress. In order to improve the GFRP composite laminate's strength and mechanical qualities, we are including graphene into our dissertation at varying percentages. The GFRP laminate will be put through a battery of ASTM-mandated tensile and flexural tests subsequently. Standardized procedures for tensile and flexural testing are used to establish ASTM guidelines. These tensile and flexural properties are used to examine the impact of graphene addition. Using this method, we can determine whether or not graphene powder can enhance the GFRP laminates' mechanical qualities.

Keywords: Glass fibre reinforced polymer, GFRP laminates, lamina plies, tensile, flexural properties. Graphene powder

INTRODUCTION

For the purpose of bettering the GFRP composites' interfacial properties, examined the results of affixing GO sheets to the GFs using covalent grafting. Vacuum molding was utilized to create GFRP composites from GO sheets grafted with GF [1]. AFM, TEM, and SEM images were used to determine the finer details of GO sheet morphology and structure. Sheets were wrinkled in the TEM pictures. As seen in AFM photos, GO sheets atop GF have the ideal thickness. The SEM pictures confirmed the immobilization of the GF surface by the GO sheets. By comparison to GFRP, the ILSS of the GO-grafted GF composite was significantly higher. This study involved the production of graphene/cellulose whiskers paper and its application to the fabrication of epoxy resin laminated films, which he then analyzed for their qualities [2]. Using ultrasonication, graphene/cellulose nano whickers were created. Using a dip coating technique, an epoxy resin sandwich is created. Tensile testing and thermal analyses were performed on the processed films. Preparation of a composite film was employed to examine its cross-sectional morphology with XRD and SEM. The XRD analysis of epoxy resin confirmed the presence of Gn/cellulose nano whickers. SEM scans showed that the Gn/cellulose nano whicker bonded more strongly to the epoxy resin than to the other nano whickers. Gn/cellulose nano whickers increased the sandwich film's tensile strength. How hot sandwiched films have to be before they stop transmitting light the enhancement of cryogenic ILSS of GFRP was investigated by Xiao-Jun Shen. Variable wt% GO GFRP composites were

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made [3]. Inter-laminar fracture surfaces were imaged using a scanning electron microscope. The developed composites showed a significant improvement in cryogenic ILSS. However, it was also shown that the ILSS decreased with increasing GO content, presumably because to the weakening of the GF and epoxy bonding caused by the GO agglomeration. Smooth and homogeneous fracture surfaces were also detected in SEM pictures. Assessments of the mechanical wear characteristics of GFRP with PTW/graphite hybrid fillers were made. The GFRP was manufactured using a vacuum bag process, and it was filled with a PTW/graphite hybrid filler of different weight fractions [4]. Hardness, tensile strength, flexural toughness, and wear were among the tests conducted on composites specimens. Inspecting the surface using a microscope equipped with a fracture detection device, cracks were found. Compared to GFRP constructed with either PTW or graphite alone, GFRP filled with a combination of the two materials had a higher tensile strength. There was a positive correlation between the weight fraction of PTW/graphite fillers and the density and Rockwell hardness values of the produced composites [5]. The composites failed the tensile test because the fibres split and the matrix plastically deformed. During a pin-on-disk wear test, it was found that the quantity of wear reduced with increasing normal force and sliding velocity [6]. The developed composites including PTW and graphite showed excellent wear resistance. Surface morphological wear and small grooves in the direction of sliding were seen in SEM images [7–8]. Findings from broken components revealed adhesive and fatigue wear, a symptom of poor typological performance. Blending a polymeric resin system with fibre reinforcement is the first step in making a composite material. It is of greatest importance that the fibres be aligned in the appropriate direction during the production process in order to achieve the desired final qualities of the composite. Producing a high volume of products at a low cost and with consistent dimensional tolerances is only one benefit of a well-designed manufacturing process [9–10].

The technology of the modern world has been evolving for decades. New and better materials are being developed for a wide variety of uses. Looking back, metal and other conventional materials were utilized in all sorts of contexts, but now, thanks to developments in material science, composite materials like polymer composites are replacing them. They're being put to use in a wide variety of contexts thanks to the high quality of their characteristics [11–12]. In comparison to more conventional materials, their density is low, and their strength-to-weight ratio is excellent; these are just a few of the many advantages they offer. Fiber reinforced polymer (FRP) is a vital material in engineering due to its low price, high stiffness, high strength, superior thermal and chemical characteristics, and low maintenance. Glass fibres (GF) are commonly employed as a reinforcing component in polymer composites due to their inexpensive cost and light weight. Glass-fiber reinforced polymer (GFRP) is a composite material made of Glass-fibers (GF) that are randomly distributed throughout the material, whether in the form of a flattened sheet (chopped strand mat) or a woven fabric. Glass fibers (GF) can be manufactured from a variety of glass types [13–14]. There is silica/silicate in all glasses, albeit the amounts of magnesium and calcium oxides and other usual chemical elements vary. Graphene has gained a lot of attention in recent years because to its exceptional mechanical, electrical, and thermal properties. Graphene's hydroxyl and even carboxyl functional groups react positively with epoxy, enhancing their adherence [15–16].

EXPERIMENT DETAILS AND OBJECTIVE

To examine the GFRP composite's mechanical properties, this study incorporates graphene powder into the epoxy resin used as reinforcement. In this research, investigate whether or not adding graphene powder to glass fibre reinforced plastic laminates (GFRP) can enhance their mechanical properties. All three therapies, plus the placebo, will be used in the research. The GFRP is treated by increasing the concentration of graphene powder added to it from 1% to 3% and then to 5%. Tensile and flexural characteristics will be investigated as a result of these treatments. Graphene's effect on GFRP laminates is studied, and the material's enhanced mechanical properties are seen. It is being looked into whether or not graphene powder (a filler material) can improve the GFRP composite's mechanical qualities. The GFRP is tested with 1%, 3%, and 5% graphene powder additions. To investigate the mechanical characteristics of these materials. Graphene's effect on GFRP laminates is studied, and the material's enhanced mechanical characteristics are seen.

METHODOLOGY

In this particular piece of research, the following technique was utilised:

- Fabrication of GFRP test specimens
- The Hand lay-up procedure is used to produce specimens for the purposes of conducting testing.
- For the research, many GFRP laminate composites are being produced.
- Fabrication is finished by adding graphene at 1%, 3%, or 5% concentration.
- Tensile and flexural tests are performed on the test specimens using UTM.

Cutting of Fabricated GFRP

High torque the hacksaw cuts GFRP according to ASTM standards. It's called an electric hacksaw. The motor is electric. Power hacksaws can be stationary or portable. For example, some stationary machines contain pumps that circulate coolant to keep the saw blade from overheating, while others lift the blade up during the return stroke. These blades have teeth that can be set to either face the handle or away from it, allowing for cutting to occur on either the push or draw motion. An electric hacksaw is employed for this purpose. The formed GFRP should be supported by a bench vice, and the hacksaw blades should be pointing forward over the work surface. The ASTM standards are used to cut the precession.

Testing Composite Laminates Mechanically

Utilizing a computerized Universal Testing Machine, produced GFRP laminates are tested mechanically. The first crosshead is used to stretch the specimen while the second is utilized to add tensile tension [12]. In addition to electromagnetic power, hydraulic models are also available. Specimens of glass fibre reinforced epoxy composites are evaluated in accordance with ASTM standards for, flexural strength, and ultimate tensile strength and using a universal testing machine (UTM) [13]. Table 1 lists the UTM's features.

Table 1. Specification of Universal Testing Machine (UTM)

Parameters	**Specification of UTM**
Length Resolution	0.01mm
Load Range	1 kg-1000 Kg Suing One Ton And 10 Ton Load Cell
Mounting	Free Standing
Length Accuracy	±0.1 mm
Grippers	Tensile, Compression And 3 Point Bending
Net Weight	230 Kg
Controls	Emergency On Off and Down Key
Cross Head Speed	0.1 To 100 mm/min

Fabrication of (GFRP) Glass Fiber Reinforced Plastic Using the Hand Lay-up Procedure

The hand layup process was used to create the composite laminates at ambient temperature. During the process of fabricating laminates, adequate care was taken to prevent voids in the material, keep the homogeneity of the material, and keep the thickness of the laminates uniform [9]. In accordance with the procedures outlined in Figure 1, the manufacture of the specimens was accomplished through the use of the hand lay-up technique. To ensure a clean release of the laminate and to prevent the laminate from sticking to the TEFLON mould, paraffin was sprayed to the mould prior to the start of the lay-up process [10]. The weight percentage ratio of fibre to matrix, which was kept at 65:35, was preserved throughout all specimens. When applying the glue to the fibres using a brush was the most effective method.

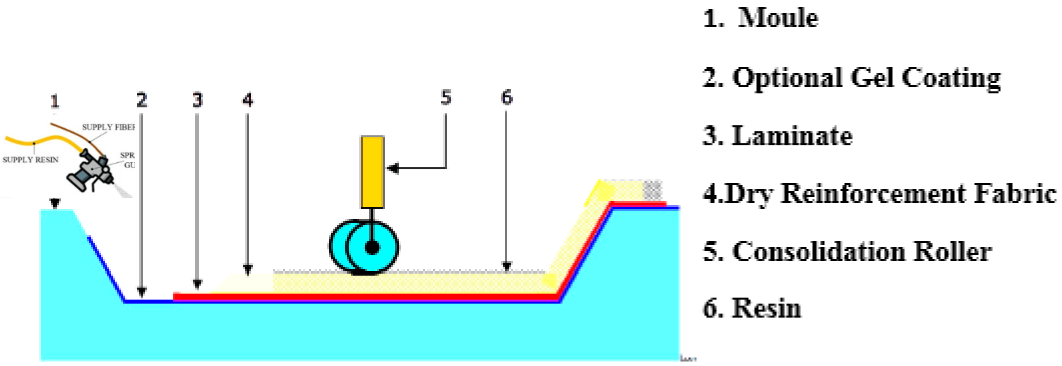


Figure 1. The specimens were made using a mechanical lay-up technique.

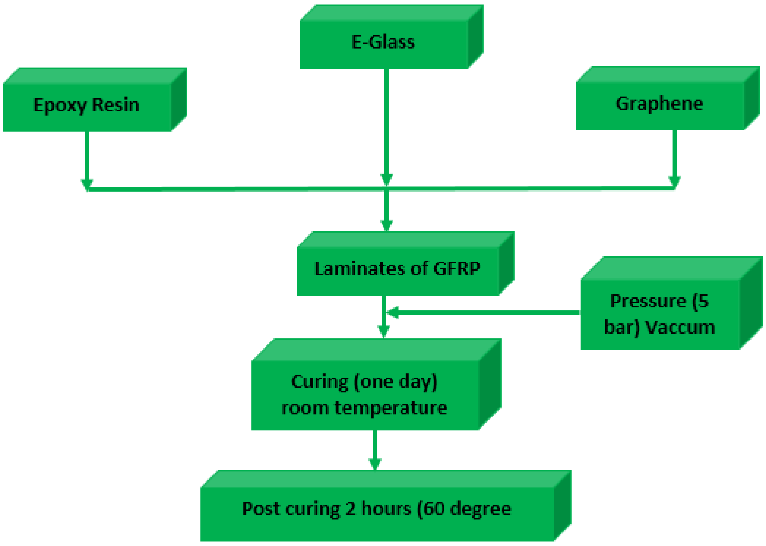


Figure 2. Workflow for GFRP Composite Fabrication.

The Methods Used in GFRP Glass Reinforced Production

There is a standard thickness of 0.3 mm for bi-woven cloths on the market, and these cloths are then cut to size and shape requirements. After the cloths have been cut into seven layers, they are stacked on top of each other until they reach the required two millimeters in thickness, as specified by ASTM regulations. Each sheet has an epoxy resin coating that is applied by hand. Curing is the process by which polymerization occurs, and it can be managed by adjusting environmental factors such as temperature, as well as by adjusting the composition of the resin and hardener used. This can take as little as a few minutes or as much as a few hours. Some formulations improve with heat applied throughout the curing phase, while others only need time and the right temperature to cure. To eliminate trapped air between the different layers, vacuuming is performed. Rooms are cured later [11]. In an Owen at a temperature of 1,000°C for up to two hours, after vacuuming and curing in the room. Figure 2 demonstrates how the cured components are cut to size and shape in accordance with ASTM standards once the curing process is complete.

RESULTS AND DISCUSSIONS

Tensile Testing of Composites

The tensile strength of these samples was determined using a total of six different specimens and varying percentages of force. It is generally accepted that the tensile force along the path of the fibres is the strongest of all directions in any laminate. In tensile strength testing, The test specimen's measurements are always 250 mm long, 25 mm wide, and 2 mm thick. Figure shows test specimens for GFRP's tensile strength. The figure below shows the strain rate of 0.2%/second that was attained by tugging at the suggested cross head speed of 4 mm/min. To achieve this strain rate, the tensile specimen was held firmly in a universal testing machine using wedge action grips. Figure 3 (A) (B) displays the dimensions acquired from ASTM D3039 for the tensile test specimen and from ASTM D7264 for the flexural test specimen.

Composites Flexural Tests (3-point Bending Test)

The flexural specimens were tested using the tried and true three-point bend test. The fracture toughness/shear strength was evaluated using a three-point bending test. It was employed to discover the mechanical characterization too. Six specimens measuring 140 mm 25 mm 2 mm in size were created. To prevent any stresses from being introduced into the GFRP Flexural test laminates during fabrication, a diamond saw was used to cut the laminates from a panel (Figure 4). The laminates are made in accordance with ASTM D7264. There was a consistent loading rate of 2 mm/min for the central flexural loading test. Only a small fraction of specimens was tested to their elastic limits, and even fewer were tested all the way to failure. Figure 5 shows 3-Point Bending Machine Tested Specimen X-RAY.

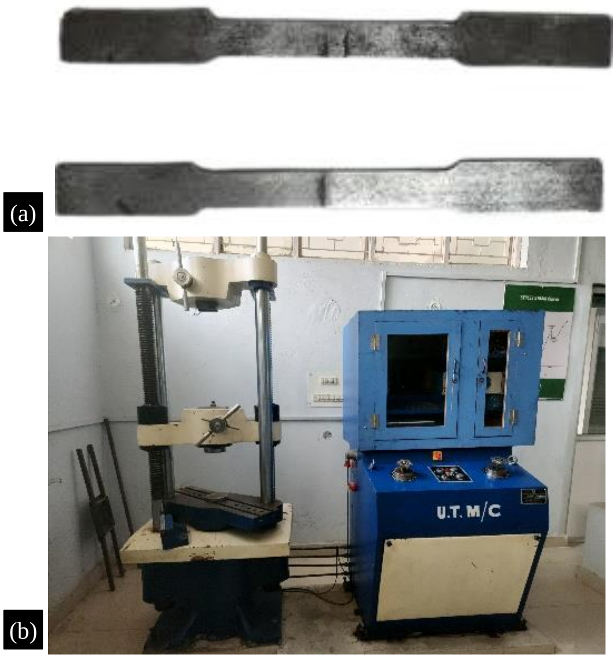


Figure 3. (A) Specimen (B) Tensile Test Specimen of GFRP testing on universal testing machine (UTM).

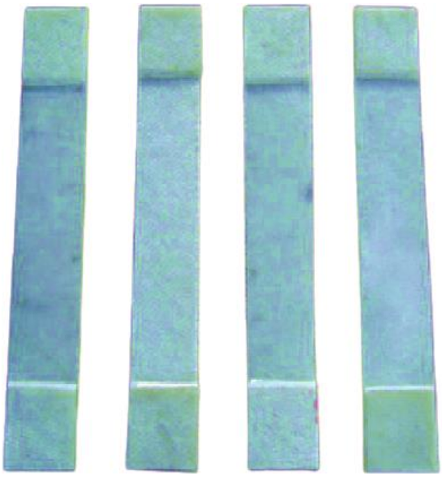


Figure 4. Flexural Test of GFRP Testing Specimen.

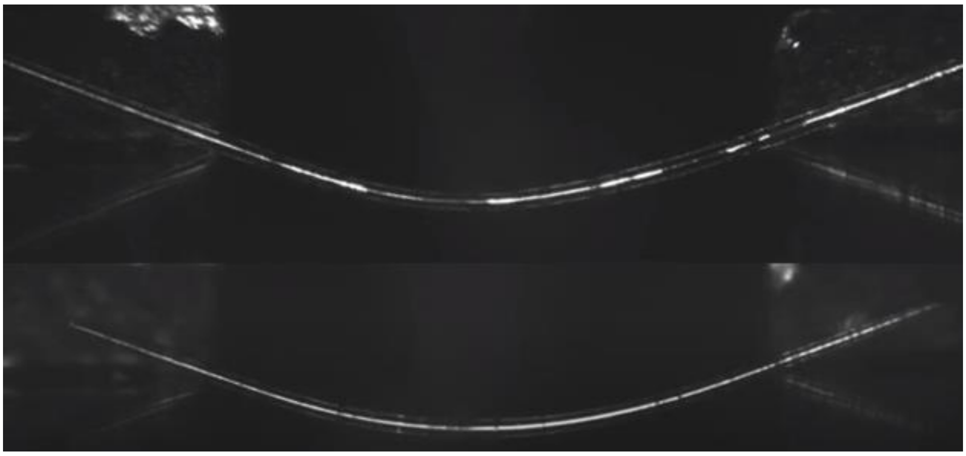


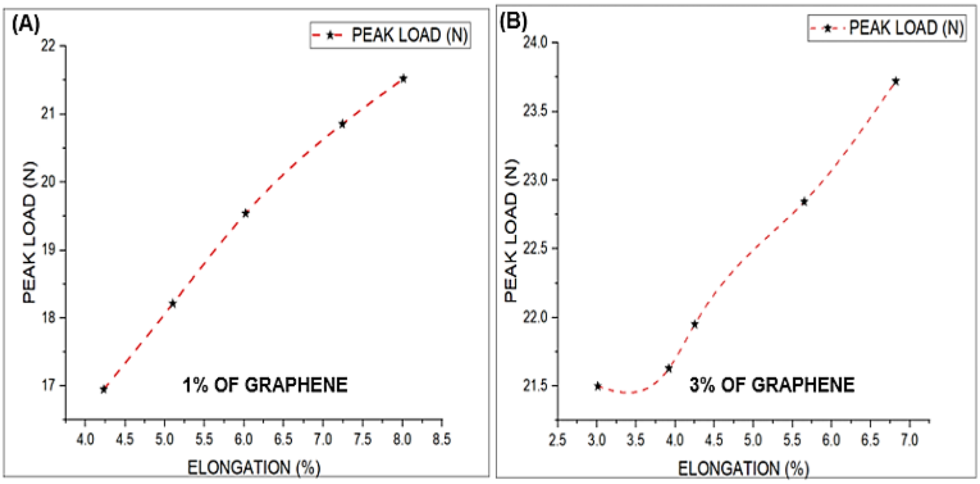
Figure 5. 3-Point Bending Machine Tested Specimen X-RAY.

RESULTS AND DISCUSSIONS

The Outcome of GFRP Composites in Tensile Tests As per ASTM D3039, GFRP was subjected to a tensile test. Laminate tensile strength was measured, and the findings are presented in Table 2. Figures 6A-C show the percentage of elongation that may be computed from the following table, which includes the initial gauge diameter and the associated change in length.

Table 2. Graphene-infused glass fibre reinforced plastic laminate tensile test results

Percentage of graphene	No of workpiece	Elongation (%)	Peak Load (N)	Ultimate Tensile Stress
1% of Graphene	1	4.23	16.950	340.5
	2	5.10	18.210	381.2
	3	6.02	19.540	390.1
	4	7.24	20.855	401.2
	5	8.01	21.521	411.2
3% of Graphene	1	3.01	21.500	410.0
	2	3.92	21.630	425.6
	3	4.25	21.950	431.8
	4	5.65	22.843	440.7
	5	6.82	23.721	448.6
5% of Graphene	1	4.35	22.102	441.4
	2	5.65	22.430	446.0
	3	6.44	22.780	452.3
	4	7.32	23.682	460.8
	5	8.75	24.532	469.5



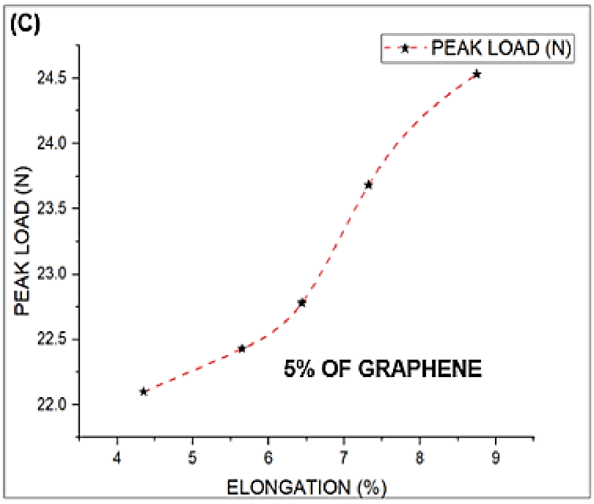


Figure 6. (A) Graph displaying the relationship between load and elongation for 1% of graphene (B) 3% of graphene (C) 5% of graphene.

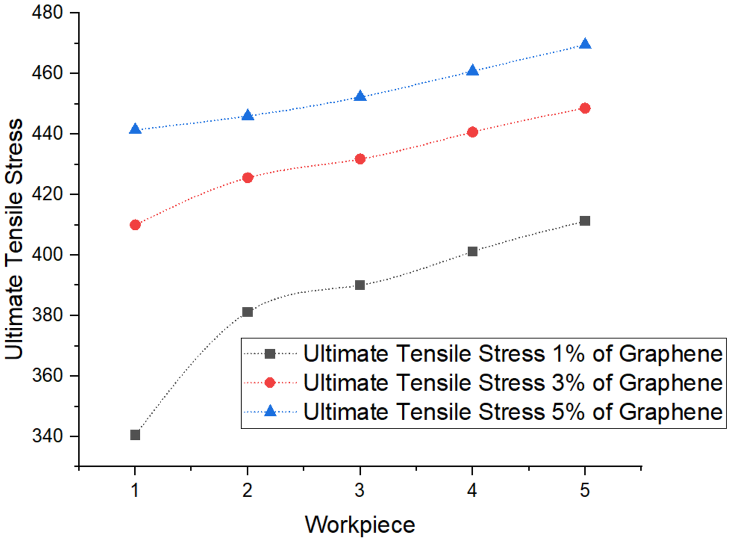


Figure 7. The Outcomes of GFRP Composite Tensile Tests.

Results of Tensile Tests

The tensile strength of GFRP composites is shown to grow linearly with load (Figure 7). This analysis contrasts three different graphene concentrations -1% graphene, 3% graphene, and 5% graphene—based on the percentage increase in each. Under these conditions, the strength is growing at a constant linear rate.

The Outcome of GFRP Composite Flexural Testing

The flexural strength of laminates was determined by conducting the test. The ASTM D7264 standards were used for this evaluation. The flexural strength of the GFRP composite was determined by a three-point bend test (Figure 5). Until failure of the GFRP composite specimen was observed, these testing continued. Tabulated below are the findings.

Flexural Test Discussion

Table 3 shows that GFRP's flexural strength increases linearly after flexural testing. Graphene percentage is compared. 1% graphene increased linearly to 5%. 5% graphene had the maximum flexural strength. Figure 8. shows that where the vertical center load acts, the topper layer compresses and the opposing layer expands. The outer, expanding layer fractures first.

Table 3. The results of flexural tests performed on GFRP laminates containing graphene

Percentage of graphene	**No of workpiece**	**Peak load (N)**	**Flexural strength (n/mm^2)**	**Maximum displacement (mm)**
1% of graphene	1	180	310.5	15.3
	2	195	320.2	14.9
	3	208	330.1	14.2
	4	218	340.5	13.8
	5	230	352.3	13.1
3% of graphene	1	216	330.2	15.3
	2	222	340.0	14.5
	3	228	349.4	13.8
	4	235	360.3	13.1
	5	247	366.8	12.6
5% of graphene	1	232	342.8	14.5
	2	235	354.7	15.8
	3	237	360.2	14.0
	4	246	365.2	13.5
	5	258	369.2	13.0

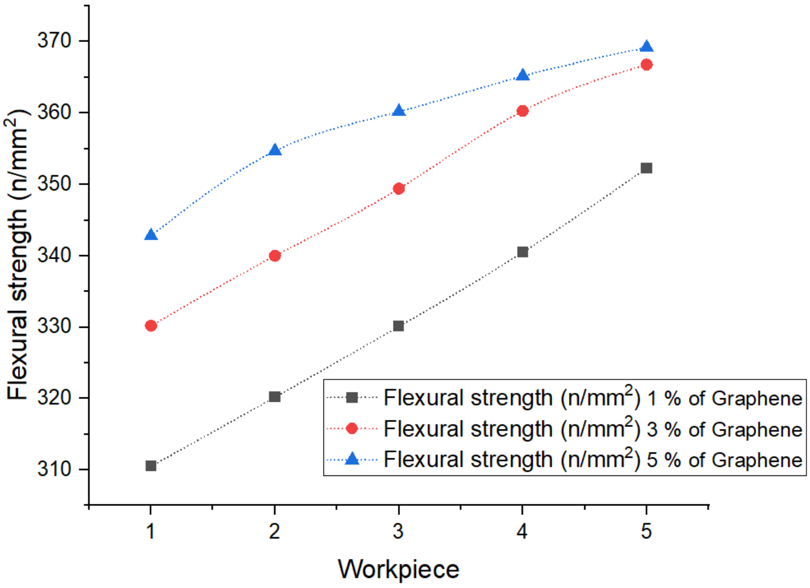


Figure 8. Flexural test results of GFRP Composite.

CONCLUSION

There has been a recent upswing in the utilisation of fibre reinforced composites in a broad number of industries, including the aviation, automotive, marine, construction, and building sectors, amongst others. Glass fibres, in particular, are playing a significant role in the development of fibre-reinforced composites as a direct result of the great mechanical strength that they possess. The results of our research into GFRP composites are presented in this chapter, along with our findings and interpretations. In the course of the research, tests of tensile and flexural strength will be carried out. The addition of graphene to the material led to a linear rise in the tensile strength of the GFRP laminates, which went from 1% to 5% when the tests were conducted on the material. The results of a three-point bending test showed that Flexural strength was improved when 1–5% graphene was added to GFRP laminates. In this work for my dissertation, we investigate whether or not using graphene powder in the manufacturing process of GFRP laminates can result in an increase in those materials' mechanical properties. The primary purpose of this research is to investigate what happens to the properties of GFRP laminates when the amount of graphene in them is increased from 1% to 3% and 5%. Finally, it was discovered that the tensile and flexural strengths of GFRP laminates may be improved by increasing the percentage of graphene present in the laminates.

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