MECHANICAL PROPERTIES OF GRAPHENE REINFORCED ABACA FIBER COMPOSITES

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Abstract. The main aim of this research work is to study the mechanical properties of abaca natural fiber composite reinforced with graphene. Natural fiber composites seek a numerous application nowadays due to its high strength is to weight ratio, high impact resistance, thermal stability, and recyclability. The percentage compositions of graphene reinforcement in the matrix are varied. Alkali treatment of abaca fiber is done to enhance bonding at the fiber-matrix interface. Conventional hand layup method is used for fabrication of the composite material. Moulds were made according to ASTM standard to test its tensile properties. The result showed that incorporation of glass fiber increases the performance of abaca fiber composites. Natural fiber composites have many potential applications in the automotive, aerospace and construction industries.

1. INTRODUCTION

Natural fibers are substances which can be directly obtained from living sources such as plants or animals. These materials are then greatly elongated to be used into making of threads, filaments and ropes. Natural fibers are a sustainable resource and have numerous benefits such as:

- High specific strength which comes from low specific weight
- A renewable resource and does not require high energy for its processing
- A desirable fiber aspect ratio
- Biodegradable and from an economical view, have a low cost per unit volume.

Natural fibers are abundantly available and they have a broad spectrum, some very well-known natural fibers are cotton, jute, hemp, jute, wool, silk and bamboo. There is a growing interest in natural fiber reinforced with composites as we aim towards sustainable development[1]. The sustainable materials are becoming increasingly popular in materials technology both in production phase and product end life as we need a method that does not affect the ecology. The increased use of natural fiber has reduced the dependency on synthetic fibers which has drastically reduced the greenhouse emissions[2].

Natural fibers are starting to find a place for them in the world of composites. Natural fibre composites have been recognized as a low-impact opportunity to other synthetic composites. The replacement of glass fibres with herbal fibres for reinforcement in polymer composites appears to be a contemporary phenomenon. NFCs have huge ability as construction substances and as a substitute of other structural substances (eg, GRP, steel, concrete) in many programs. Their numerous applications extend to architecture, automotive as well as aerospace. The use of natural fibers have been noticeably effective in reducing the greenhouse emissions [3]. High Density Polythene (HDPE) can be replaced by natural fibers, various reasons include natural fibers being low density, low cost and high specific
properties characteristics. HDPE which is a petroleum-based synthetic fiber has caused irreversible damage to our environment due to them being non-biodegradable. Natural fibers are evolving rapidly and soon may replace metals and ceramics.

There have been numerous research conducted on natural fibers but very few have been found for abaca fiber. Abaca fiber is obtained from the leaf sheath from the trunk of Musa textilis. Abaca is fine and light beige in appearance. It has a high lignin content, it can be as high as 16%. It is best known for its high strength and long fiber lengths (up to 3m). Abaca has a huge potential as it can substitute glass fiber in various automotive parts and it is currently known better for producing paper products, twines, nets and fishing nets. Some recent studies also show the potential of abaca fiber to replace the man made fibers and many other natural fibers in various other applications. It has been known that the tensile strength increases as we increase the percentage of fiber reinforcement[4].The waxy residuals are removed[5] after the alkali treatment (5% NaOH) which enhances the surface wettability, resulting in enhancement of interfacial adhesion. The fibers are able to rearrange themselves along the direction of tensile deformation due to the alkali treatment performed which removes noncellulosic impurities and materials from the interfibriller region[6]. The property of the composite is highly dependent on interfacial adhesion. The fiber is made more hydrophobic by removal of hydroxyl coat and hence it absorbs less moisture.

For the tensile test we try a combination of fiber-epoxy-graphene reinforced resin as we have been coming across the numerous features of graphene such as a young’s modulus of 1.0 ± 0.1 TPa for a thickness of 0.355nm[7]. A monolayer of graphene has an inartistic strength of 130GPa. It has a fracture toughness which is measured as a critical stress intensity factor of 4.0 ± 0.6 MPa. We have used the process of sonification to make sure that the graphene is dispersed completely into the epoxy. Sonification uses sound waves at a predetermined frequency and for our findings we used a frequency of 35Khz and our mixture was immersed in a water bath for two hours for the sonification process to take place. We have made four different percentages of graphene and epoxy mixture. 0%, 1%, 2%, 3% and 4%.

In this paper, the tensile behavior of fiber-epoxy reinforcement and the behavior of fiber-epoxy-graphene reinforced resin for different percentages of graphene are analyzed. The comparisons are done and varying results are concluded.

2. Materials

Viscous epoxy resin and Polyamine hardener is used for making the matrix system. Abaca fibre (also known as Manila hemp) is used. Research grade Graphene (Purity>99%, diameter: 0.8-2 nm) is used for experimental purpose. All the materials used in this research work is shown in the figure.
3. METHODS

a. Alkali Treatment of Fibre

About 300 gm of abaca fibre was treated in 1L 0.5% NaOH solution. The fibers were kept in alkaline solution for about 15 minutes at ambient temperature. The alkali treated fibers were then washed with distilled water. Then fibers are cured in room temperature for about 72 hours as shown in figure 2(b). Alkali treated fibers composites have better mechanical properties compared to composites containing untreated fibers.[8]

\[
\text{Fiber} - \text{OH} + \text{NaOH} \rightarrow \text{Fiber} - \text{O- Na} + \text{H}_2\text{O}
\]

b. Preparation of Mould

Moulds were made according to ASTM standards D638 and D790 using wood as shown in the figure



Figure 3.2. ASTM D638 standard mould

c. Ultrasonification

Ultrasonification of Graphene powder in epoxy resin is done prior to the fabrication of composites. An ultrasonic frequency was used to agitate Graphene particles in the epoxy
solution. The research grade graphene with a purity of 99 wt.% was used for this research work. Concentration of 0-04% in the incremental steps of 1% by the weight % of the epoxy matrix was used. The Resultant mixture and hardener were mixed in the ratio 10:1. Dispersion of graphene in resin was done using sonication method as shown in the Figure 3.3. For further dispersion the mixture was mixed mechanically till it becomes homogeneous.

![Ultrasonification Process](image)

**Figure 3.3: Ultrasonification Process.**

d. Preperation of Composites

Steps involved in preparing the Graphene reinforced Abaca fibre composites are as follows:
The alkali treated fibers are randomly arranged such that they form uniform strings. Fibers are cut according to the dimension of ASTM D638 mould. Epoxy-Hardener is mixed in the ratio of 10:1(%Vol) for minimizing the fiber pullout, this also increases the fiber matrix interface. Fiber composites are prepared using a conventional hand lay-up method, followed by a compression molding technique. Composition of graphene is varied as shown in the table. The composites are varied as shown in the Figure 4.

| Sample | Sample Composition            | Alkali Treatment                     |
|--------|--------------------------------|--------------------------------------|
| S1     | Epoxy + Abaca Fibre + 0% Graphene | 5% NaOH Treated Abaca fiber           |
| S2     | Epoxy + Abaca Fibre + 1% Graphene | 5% NaOH Treated Abaca fiber           |
| S3     | Epoxy + Abaca Fibre + 2% Graphene | 5% NaOH Treated Abaca fiber           |
| S4     | Epoxy + Abaca Fibre + 3% Graphene | 5% NaOH Treated Abaca fiber           |
| S5     | Epoxy + Abaca Fibre + 4% Graphene | 5% NaOH Treated Abaca fiber           |

4. EXPERIMENTAL PROCEDURE
The Specimens were made according to ASTM D638 standard and the tensile test was conducted on Digital tensile testing machine INSTRON 8801, as shown in Figure 5.2. The specimens were securely clamped by the top and bottom grips attached to the tensile testing machine as shown in the Figure 5.2.

During the tension test grips are moved apart at constant rate of 10mm/min to stretch the specimen.

The gage length of the tensile specimen was 80mm.

The force acting on the specimen and its displacement was analyzed and graph was plotted until the specimen fails.

After a certain load, the specimen breaks into two pieces as shown in the Figure 5.3.

![Figure 4.1 0% Graphene S1](image1)

![Figure 4.2 1% Graphene S2](image2)

![Figure 4.3 2% Graphene S3](image3)

![Figure 4.4 3% Graphene S4](image4)

![Figure 4.5 4% Graphene S5](image5)
Table 4. Specimen Characteristics for Tensile Testing

| Characteristics        | Particulars                      |
|------------------------|----------------------------------|
| Size                   | 165mm x 20mm x 5mm               |
| Epoxy Resin used       | LY556                            |
| Resin Hardener         | Polyamine Hardener(HY951)        |
| Natural Fibre          | Alkali Treated Abaca Fibre       |
| Graphene %             | 0%, 1%, 2%, 3%, 4%               |

5. FABRICATION & TESTING OF COMPOSITES

Composites were made using convention hand layup Technique

Figure 5.1 Test Specimen containing 0%, 1%, 2%, 3%, 4% Graphene Concentration respectively.

Figure 5.2 Tensile Testing was carried out in digital tensile machine INSTRON 8801.
6. RESULT AND DISCUSSION

The load-displacement curves for the Abaca Fibres, composites are obtained from digital tensile testing machine and are shown in the following figures. The utmost stress is in accord with its maximal load. The concept of tensile strength used in this study, is defined as the maximum stress on the stress-displacement curve, being directly propositional to the maximum load.

It was observed that as the percentage of Graphine was increased by 1% in the ASTMD638 made of Abaca Fiber, Epoxy and Graphene, the strength of the composite increased. The tensile strength of composite with 0% of Graphine was 402 N which is 10% less than the Graphene with 1%. The maximum value of stress in case of Abaca Fiber-Epoxy-Reinforce Composite (Uniaxial Fiber Arrangement), containing 4% Graphene, was 1045 N.

Figure 6.1 Load v/s Extension graph for 0% Graphene reinforced abaca fiber composite.
Figure 6.2 Load v/s Extension graph for 1% Graphene reinforced abaca fiber composite.

Figure 6.3 Load v/s Extension graph for 2% Graphene reinforced abaca fiber composite.

Figure 6.4 Load v/s Extension graph for 3% Graphene reinforced abaca fiber composite.
Figure 6.4 Load v/s Extension graph for 4% Graphene reinforced abaca fiber composite.

Table 6. Summary of experimental results of tensile test.

| Sample | Maximum Load (N) | UTS (GPa) | Modulus (Automatic Young's) (MPa) | Tensile strain at Break (Standard) (%) |
|--------|-----------------|-----------|----------------------------------|--------------------------------------|
| Sample 1 | 402.6532        | 0.005     | 2293.250                         | 1.792                                |
| Sample 2 | 447.7500        | 0.005     | 3135.018                         | 2.174                                |
| Sample 3 | 570.1184        | 0.007     | 2525.061                         | 3.359                                |
| Sample 4 | 805.4971        | 0.010     | 2284.226                         | 2.461                                |
| Sample 5 | 1045.691        | 0.013     | 2116.578                         | 2.339                                |
| Maximum  | 1045.691        | 0.013     | 3135.018                         | 3.359                                |
| Mean     | 654.3421        | 0.008     | 2470.827                         | 2.425                                |
| Minimum  | 402.6532        | 0.005     | 2116.578                         | 1.792                                |

7. CONCLUSION
The ASTM D638 specimen was prepared using, abaca fiber reinforced with epoxy and Graphene and its tensile strength was examined. It was evident that fibers treated with alkali sodium hydroxide (NaOH) indicate better mechanical properties as it enhance bonding at the fiber-matrix interface. Out of all the combinations used in the experiment with graphene, the composite with 4% Graphene had the maximum tensile strength. From this result, it can
be inferred that, Graphene increases the tensile strength of the composite, approximately by 15% (if increased by 1% each time). According to the application theory, the arrangement of the Uniaxial, provides the maximum tensile strength. An average of 20% increase was indicated in the experiment, after adding 1% graphene in each composite. The composite created in the study shows its utilization in almost all the areas, apart from the area of medical sciences. It can be used as a substitute in the automobile Industry.

8. REFERENCES

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