Effect of Graphene Addition on Sisal-Glass Epoxy Composite

Sooraj S[1*], Hari Sankar S[1], Krishnarjun K. G[1], Dileep K Das[2]

[1]UG Student, Dept. of Mechanical Engineering, Sree Narayana Institute of Technology Adoor, Pathanamthitta, Kerala, India

[2]Assistant Professor, Dept. of Mechanical Engineering, Sree Narayana Institute of Technology Adoor, Pathanamthitta, Kerala, India

*Corresponding author's e-mail: soorajsooraj710@gmail.com

doi: https://doi.org/10.21467/proceedings.160.63

ABSTRACT

Natural fiber or synthetic fiber can be utilized separately as reinforcing fiber in traditional composites. Sisal is a natural fiber which possesses high strength to weight ratio, durability, ability to stretch in which they are primarily used in applications where the materials must withstand extreme environments such as aerospace, automotive industries. To enhance the natural fiber reinforced composite's (NFRC) mechanical qualities A sisal-glass hybrid composite made from graphene was created using woven glass fiber. Glass and sisal fibers serve as reinforcement materials, and epoxy L-12 serves as the matrix phase. The matrix is also injected together with reduced graphene oxide (rGO). Chemical processing was used to remove the cellulose from raw sisal fiber. The compositions used for the tests are (85% - 15%) with 0.5 weight percent, 1 weight percent, and 5 weight percent rGO added by compression moulding process. In order to assess the mechanical qualities, tests for impact, hardness, and thermal conductivity are performed.

Keywords: Hybrid composite, Reduced Graphene oxide, Thermal conductivity

1 Introduction

Natural fibers extracted from plants have attracted a lot of attention for use as composite reinforcement. These fibers have good reinforcement properties when used with polymer matrices and are made from naturally renewable resources. Natural Fiber Reinforced Polymer (NFRP) Composites replace standard materials owing to its low weight, high-ratio of strength to weight, and stiffness qualities [1]. NFRP is a promising material in the aircraft and automotive sectors as an outcome of its alluring mechanical and tribological properties. Natural fibres come in a variety of forms, which include the likes of jute, cotton, sisal, kenaf, and more. The possibility exists for sisal fiber to replace synthetic fibres in the production of environmentally friendly structural composites. High strength-lightweight, design flexibility, minimal moisture absorption, corrosion resistance, dimensional stability, minimum finishing required are the properties obtained from FRPs [2]. The leading markets for natural composite materials are the car sector, which uses them in interior applications including door panels and trunk liners [3].

Hybrid composites are Blending one or more different types of fibres in just one matrix. Sisal and glass fiber were used in this work as the reinforcing phase, and reduced graphene oxide (rGO) epoxy was used as the matrix phase [4]. To create a hybrid composite, sisal, a natural fiber, is combined with glass, a synthetic fiber, in a matrix epoxy. A potential reinforcement material for polymer composites is sisal fiber. Beyond its conventional uses (ropes, carpets, mats, etc.), it may find use in the automotive and aerospace industries. Sisal fiber is obtained from agave sisalana and it consists of 78% cellulose, 10% hemicellulose and 8% lignin. The most popular man-made fiber, aside from natural fiber is glass fiber (GFs) due to their cheap price, great mechanical performance, excellent heat resistance etc [5]. A number of people are interested in using glass fiber to strengthen polymer matrices. Epoxies, polyester, and vinyl esters are the thermoset resins that are most frequently utilized in automobile applications. Epoxy resins have more appeal in the automobile industry since they are high performing and resistant to environmental deterioration. They may be the best value for your money due to their wide range of mechanical properties. As a substitute for FRP composites,

Proceedings DOI: 10.21467/proceedings.160; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-9-9

to enhance the physio-mechanical qualities, such as impact strength, hardness, and thermal conductivity, graphene oxide (rGO) is fused with epoxy resin [6].

By using chemical processes including bleaching, steam explosion, and alkaline treatment, the cellulose found in natural fibers was removed [7]. The composites are made using a compression moulding process with four distinct matrix-cellulose weight percentages: 85-15, 0.5, 1, and 5%. These ratios' mechanical characteristics are looked into. The stainless-steel mould being utilized has a capacity of 200x200x3mm. According to ASTM standards, mechanical qualities including impact resistance and hardness as well as heat conductivity were studied.

2 Materials Used

2.1 Fibers used

Raw sisal fiber for cellulose extraction or reinforcement preparation were purchased from Chennai shown in figure 1 and Glass fiber used is in the form of woven mat figure 2. Peculiarities of sisal fiber is mentioned in the table 1 [8].

Figure 1: *Sisal fiber*

Figure 2: *Glass fiber*

Table 1: *Pecularities of Fiber-Sisal*

Properties	Values
Density	1.450 g/cm^3
Diameter	100-300 µm
Cellulose	65%-78%
Hemicellulose	10%-14%
Lignin	9.9%

2.2 Chemicals used

The chemicals used for cellulose extraction of fibers are Sodium hypochlorite, NaOH, Acetic acid. These chemicals are used for preparing solutions for alkaline treatment and bleaching process for the extraction of cellulose and lignin content from the sisal fiber.

The resin used is epoxy (Lapox) L-12. The hardener used is tri ethylene tetra amine (TETA), often known as K-6.

3 Chemical treatment

3.1 Alkaline treatment

Alkaline treatment is carried out with 5% of NaOH for 2 hours at room temperature. The alkaline mixture is prepared by adding 20g of NaOH pellets dissolved in 500 ml of water in 4 beakers. 50-100g of fibers were soaked in each beaker as shown in figure 3 [9]

3.2 Steam explosion

Steam explosion process is to remove hemicellulose and lignin content in the fibers. It is carried out in autoclave machine. The alkali treated fibers were placed on autoclave for 1 hour at 10lbs pressure at room temperature of 100ºc

3.3 Bleaching

This process is done by preparing two solutions that is solution A and B. To prepare solution A, 26g of NaOH is mixed with 73.5g acetic acid which is then added to 900ml of water. The solution B is made by dissolving 250ml of Sodium Hypochlorite solution in 750ml of water. Then both the mixtures A and B are taken out by 1:1 ratio and then the fibers are dipped in it shown in figure 3. The fiber turns white color when the hemicellulose parts are removed shown in figure 4.

Figure 3: Alkaline treatment

Figure 4: *After bleaching process*

4 Composite preparation

Compression moulding is used to manufacture the composite in the ratio of 85%-15%. This method is efficient and frequently used for thermoset polymer composites with fiber reinforcement [10]. Neoplast's compression moulding machine was used for the compression moulding figure 5.

Figure 5: *Neoplast compression moulding machine*

The mould used is having a dimension of (300x300x3) made up with the stainless steel is shown in figure 6. The stainless-steel mould is used because it has a propensity to oxidize in areas with high humidity and warm climates, leading to parting-line degradation and pitting of the moulding surfaces. In these circumstances, stainless steel mould materials are mostly employed. Fabrication of composite was held at Central Institute of Petrochemicals Engineering & Technology (CIPET) Kochi.

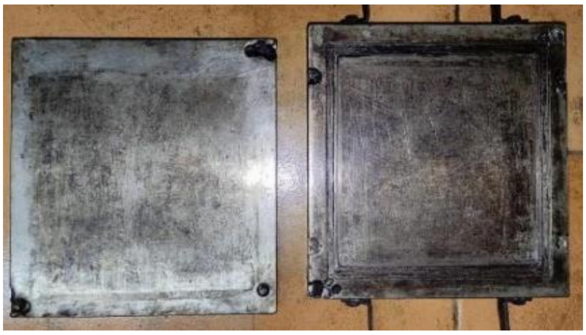


Figure 6: *Stainless steel mould*

The sample is prepared by using the reinforcement and epoxy resin. The hardener K-6 and reduced graphene oxide is added with the resin at three distinct compositions 5wt%, 1wt%, and 0.5wt%. After pouring the initial layer of epoxy into the mould, reinforcement sisal-glass is added and dispersed over the layer of epoxy matrix. The reinforcement is covered with the last layer of epoxy mixture once more. Closing the mould and applying automated compression pressure. The layout of compression moulding machine is shown in figure 7. Effective compaction requires the application of 83.5 bar pressure for two hours. The same procedure is used to prepare all of the composite's figure 8. The composition of the composites is shown in table 2.

Table 2: *Sisal-glass-epoxy composites' composition*

SI NO	Composition of sisal–glass–epoxy composites				
	Epoxy (g)	*Hardener (g)*	*Reduced graphene oxide (g)*	*Sisal fiber (g)*	*Glass fiber (g)*
1	120	30	-	32	22
2	120	30	.75	32	22
3	120	30	1.5	32	22
4	120	30	7.5	32	22

Proceedings DOI: 10.21467/proceedings.160
ISBN: 978-81-965621-9-9

Series: AIJR Proceedings
ISSN: 2582-3922

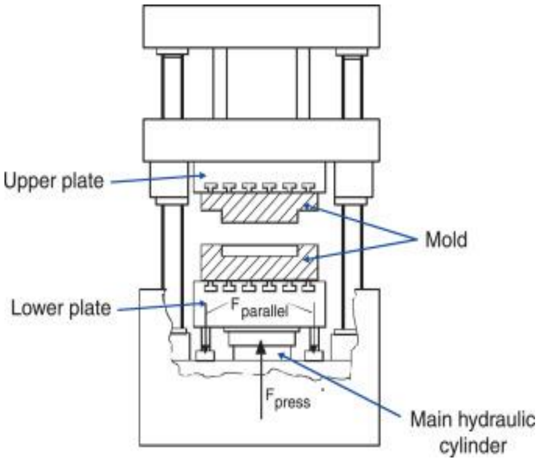
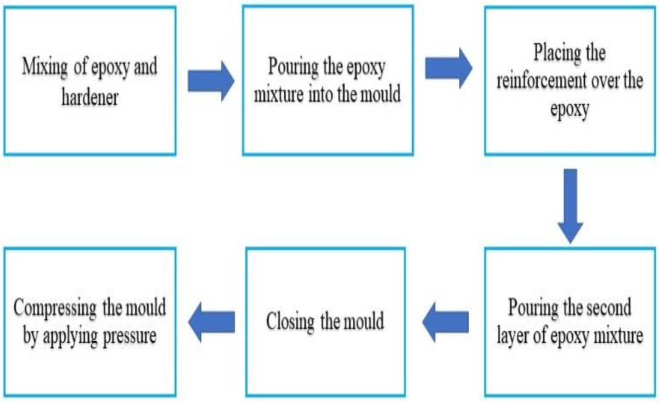


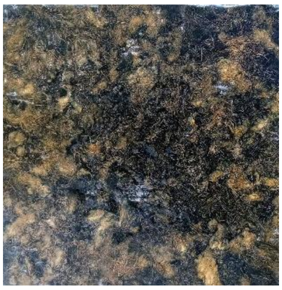
Figure 7: *Compression moulding*



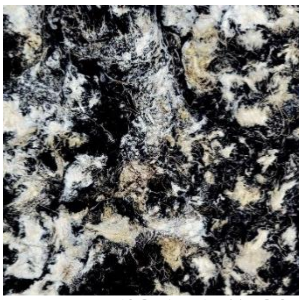
Flow diagram of composite fabrication

E85SG15

E85SG15 + 0.5wt% rGO



E85SG15 + 1 wt% rGO



E85SG15 + 5wt% rGO

Figure 8: *Prepared sisal-glass-epoxy composites*

5 Mechanical Characterization

5.1 Hardness

The materials ability to resist surface deformations is directly associated with hardness. Hence it is essential to undertake hardness test on the fabricated samples to evaluate the degree of wear and tear on the surface. The hardness test was conducted by using Mitutoyo hardness durometer which has a pyramid shaped indentation pin to check the hardness of the sample. Shore hardness are mainly used for testing the materials like soft rubbers, rigid plastics, elastic materials.

5.2 Impact testing

Izod impact testing equipment was used to determine the samples' impact resistance. Samples are made in compliance with ASTM D 256 specifications for the impact test. After being fastened onto the fixture for impact test is one in which the specimen is permitted to be impacted by the pendulum while having the serrated side facing to the pendulum's hitting edge.

5.3 Thermal conductivity

The capacity of a substance to transport heat from one type of heated end to a distinct type of unheated portion of the same substance is known as thermal conductivity. An oil burner is employed to test thermal conductivity of the samples. The burner's flame came into touch with one edge of the test samples and the temperature of the sample bar's heated and nonheated edges was determined by using a thermometer [4].

6 Result and Discussions

6.1 Hardness test

Table 3: *Hardness Test Readings*

Sample	Shore D hardness
E85SG15	69
E85SG15 + 0.5 wt.% rGO	72
E85SG15 + 1 wt.% rGO	73
E85SG15 + 5wt.% rGO	76

The Shore (A) hardness was conducted by Mitutoyo hardness durometer. The tester was positioned vertically and the samples were placed on a horizontal platform. An average of three readings was recorded when the Durometer's pyramid-shaped indentation pin was pushed on the specimen and the pressure foot stayed parallel to it. Samples of dimensions 30×30×3 mm are prepared to conduct the hardness test. The hardness value was obtained and average value of each sample is taken as shown in table 3.

In comparison to other compositions, the composite with 5 weight percent rGO has the highest hardness rating. The harder samples are those with higher levels of reduced graphene oxide. The variation of the results is plotted in figure 9.

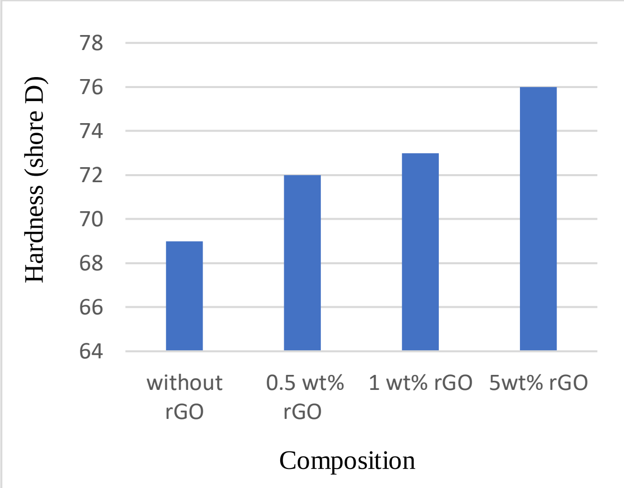


Figure 9: *Hardness of composites*

6.2 Impact testing

Using an Izod impact testing machine, a notched Izod test was performed to examine the impact properties of specimens. Samples of dimensions 65×13×3 mm with a v notch exactly at the center are to be prepared to conduct the impact test. The average value of each sample is shown in table 4.

Table 4: *Impact Test Readings*

Sample	**Izod impact strength (kj/m^2)**
E85SG15	3.54
E85SG15 + 0.5 wt% rGO	3.87
E85SG15 + 1 wt% rGO	3.79
E85SG15 + 5 wt% rGO	4.26

The composite highest impact strength was obtained for the composites with 5wt% rGO 4.26 kj/m^2. The sample lacking rGO has the weakest influence. The sample prepared with 0.5wt% rGO has a higher impact strength than the sample prepared with 1wt% rGO. The obtained results are represented in figure 10.

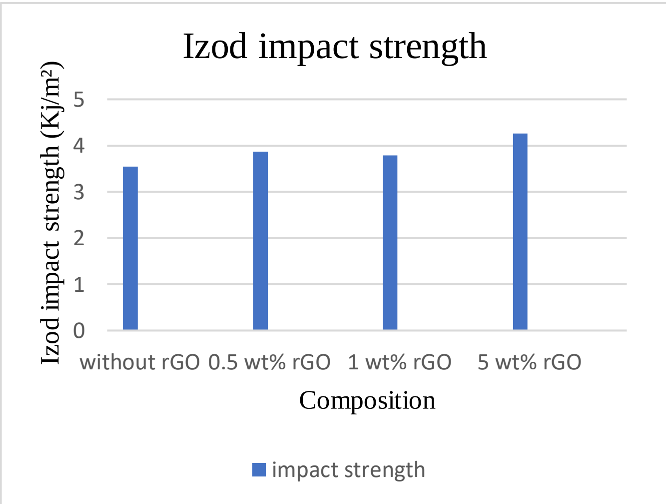


Figure 10: *Impact strength values*

6.3 Thermal conductivity

The sample's heat conductivity was measured using a thermometer. After heat for 1 minute, the heated portion of the composite without rGO was discovered to be 79 °C, as opposed with the non-heated side's 34 °C. The heating time was also prolonged by two minutes throughout the test. The specimen under test, which wasn't made utilizing rGO, had a temperature difference between the heated and unheated ends. The temperature difference between the heating and unheated ones ends of the mixed samples made with rGO (0.5 wt.%, 1 wt.%, and 5 wt.%) was measured using a similar technique. The blended sample with 5% rGO exhibited the highest thermal conductivity, at 90.9%, in accordance with the test results in table 5.

Table 5: *Thermal conductivity comparisons of samples*

	Samples			
	Without rGO	***0.5 wt.% rGO***	***1 wt.% rGO***	***5 wt.% rGO***
After heating for 1 minute				
Heated end (ºC)	79	70	73	71
Non-heated end (T1) in (ºC)	34	37	41	47
After 2 min of heating				
Heated end (ºC)	91	101	103	109
Non-heated end (T2) in (ºC)	45	52	57	68
Difference, T3 = (T2-T1) in (ºC)	11	15	16	21
Conductivity increased when compared to sample without rGO (T3 − T4/ T4 x100%)	0%	36.36%	45.45%	90.9%

7 Conclusions

Samples with varying percentage of Reduced graphene oxide were prepared and these inferences were made based on the test results.

- The sample made with 5 weight percent of rGO had the highest hardness strength, measuring 76 N/mm^2.
- Sample containing 5wt.% or rGO has the highest impact strength and lowest value was recorded for sample without rGO.
- The thermal conductivity of the composite containing 5 weight percent rGO was higher, at 90.9%.
- The mechanical qualities of the composite can be improved by the inclusion of reduced graphene oxide.

Proceedings DOI: 10.21467/proceedings.160
ISBN: 978-81-965621-9-9

Series: AIJR Proceedings
ISSN: 2582-3922

8 Declarations

8.1 Acknowledgment

We thank everyone of the Mechanical Engineering Department's teaching and non-teaching staff members who directly and indirectly assisted us in finishing this paper work.

8.2 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Sooraj *et al.* (2023). Effect of Graphene Addition on Sisal-Glass Epoxy Composite. *AIJR Proceedings*, 505-513. https://doi.org/10.21467/proceedings.160.63

References

[1] Michael A. Fuqua, Shanshan Huo, Chad A. Ulven, "Natural fiber reinforced composites" 2012, *Polym. Rev. 52 (3)* 259–320.

[2] S. Prashanth, K.M. Subbaya, K. Nithin, S. Sachhidananda "Fiber reinforced composites" 2017, J. *Mater. Sci. Eng 6 (3)* 2–6

[3] Sandeep Olhan, Vikas Khatkar, B.K. Behera, "Textile-based natural fibre-reinforced polymeric composites in automotive" *2021 Composite.Sci. 56 (34)* 18867–18910.

[4] A.K.M. Nayab-Ul-Hossain, Salma Katun Sela, Md.Abdul Hasib "Preparation of graphene based natural fiber (Jute)-synthetic fiber (Glass) composite and evaluation of its multifunctional properties" Composites Part C: Open Access Volume 9, *2022, 100308*

[5] A. K. Bledzki and J. Gassan "Composites reinforced with cellulose based fibres" *Prog. Polym. Sci. 24,* 224–274

[6] Sekhar C Ray,"Application and uses of graphene oxide and reduced graphene oxide, Appl. Graphene and Graphene-Oxide Based Nanomaterials" 2019, *Mater. Sci. Eng 6 (3)* 26-42

[7] E. T. N. Bisanda and M. P. Ansell "The effect of silane treatment on the mechanical and physical properties of sisal–epoxy composites" *Compos. Sci. Technol. 41,* 165–178.

[8] Yang, G.C., Zeng, H.M., Jian, N.B. and Li, J.J. "Properties of Sisal Fiber/Glass Fiber Reinforced PVC Hybrid Composites", *Plastics Industry, 1: 79–81.*

[9] Arun M, Gokul K G "Synthesis and Mechanical Characterization of Cellulose Reinforced Epoxy Polymer Composite" *98 Second International Conference on Mechanical, Automotive and Aerospace Engineering 2016*

[10] Vamsi Krishna Balla, Kunal H. Kate, Jagannadh Satyavolu, "Additive manufacturing of natural fiber reinforced polymer composites: processing and prospects",2019, *Compos. Part B: Eng*. 174 106956