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Improvement of Mechanical Properties of Alumina in Glass/Jute/Coir Reinforced Nanocomposite

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Abstract

The objective of this study is to create a unique material that will meet the criteria of structural applications on automobiles and aircraft using composite technology. Currently, fully synthetic fiber is corrosive, hefty in weight, and reactive to chemicals. As a result, we require an alternative material that can handle such challenges. The composite panels made of jute, coir fiber mat, glass fiber have a smooth, beautiful, and high specific strength ratio. The mechanical characteristics of fiber reinforced polymers were examined after nano aluminum oxide (Al_2O_3; alumina) fillers were introduced in varied weight ratios. As a result, such panels are favored in airplane construction, vehicle structural applications, furniture development, and so on.

Keywords

Alumina, Reinforcement, Mechanical properties, Nanocomposite

Introduction

Polymeric composites have expanded at an incredible rate, and these materials today have an astounding and diversity of uses [1]. Composites have several benefits over many metal alloys, including low density, strong fatigue resilience, superior corrosion resistance, thermal insulation, and low thermal expansion. Polymer matrix composites offer outstanding mechanical and chemical characteristics, plus high specific strength, and modulus, in addition to resistance to fatigue and corrosion. Polymer-based composites show an important and significant part in modern world because of its desirable characteristics like being lightweight, robust, recyclable, biodegradable, plentiful in nature, and has a minimal cost and low density. They are utilized in a variety of sectors including automotive, aerospace, maritime, and construction. Direct to maximize the performance of natural fiber composites, it is critical to learn more about the composite. Much research has been published on the characterisation of natural fibers such as coir, jute, flax, basalt, glass, kenaf, and tamarind in a polymer matrix, for a variety of technical applications.

The research focused on investigating how the amalgamation of fly-ash filler affected the mechanical properties of composites enforced with jute, banana, basalt, and carbon textiles. The findings definitely show that the use of fly-ash filler improved the tensile and flexural characteristics. When tensile characteristics are critical, the 4 wt.% fly-ash nano-filler basalt-jute-basalt-carbon hybrid composite outperforms the jute, banana, basalt, carbon textiles reinforced epoxy hybrid composites. Where the flexural characteristics are protuberant, the 4 wt.% nano fly ash basalt-jute-basalt-carbon hybrid composites are a superior alternative than basalt/jute/banana/carbon textiles hybrid composites. Morphological investigations demonstrate that filler additions boost the strength of carbon/jute/banana/basalt fiber enforced epoxy polymer composites. The samples are created in three layers, one of which is similar to jute, glass, and jute fiber, while the other is similar to jute, glass, and jute fiber enforced with resins. The tensile strength for the two materials is tested and found to be 12.121 N/mm^2 and 22.798 N/mm^2. The glass, jute, and glass enhanced fiber natural composite generated higher strength (22.798 N/mm^2) with 3.44% extension, indicating that it appears highly ductile in nature. The exact gauge length of 50 mm is determined. After tensile testing, the ultimate gauge length composite consisting of three layers samples such jute, glass, jute fiber and glass, jute, glass fiber concurrently is 50.9 mm and 51.72 mm.

The inter-ply macroscale hybridized procedure greatly enhanced the mechanical characteristics of the material. The tensile strength of the composite rose by 69%, the flexural strength by 38%, the flexural stiffness by 112%, and the impact energy by 301%. When contrasted with simple inter-ply hybridization, multiscale hybrid synthetic fiber + natural fiber with filler enforced composites demonstrated a minor improvement in composite effectiveness. The failure mechanisms of the nano-filler adjusted materials changed as the filler reinforcement changed. In the tensile tests, every sample demonstrated brittle failure of the jute fiber, subsequently assessment total or imperfect surface fiberglass fiber facture and delamination, but in the flexural testing, many samples had compressive fiber buckling failure. Lastly, all hybrid samples failed the impact tests for the reason that brittle failure of the jute core, considerable deformation or entire sample failure, in addition to delamination and surface fiber glass collapse. Jute epoxy composite containing titanium dioxide (TiO_2) reinforced particles created in various jute woven fiber orientations. The dispersion of particles and the interphase relationship among the filler and the matrix enhance the tensile and flexural properties of the composite. The TiO_2-reinforced composite displayed the most substantial enhancement in both tensile and flexural strength (2 wt.%) comparing to the unfilled composite was tested with jute fiber mats oriented at a 90˚ is 30.79% and 38.44%, respectively. The wear rate of composite was found to be substantially greatest at 60˚ collision at all compositions, and with the inclusion of TiO_2, the wear rate somewhat increased in 45˚ and 60˚ fiber orientation but significantly lowered in 90˚ fiber alignment. The incorporation of the filler improves the hardness, load-bearing capability (tensile strength), and resistance to bending (flexural strength), shear resistance of individual layers, and impact resilience, were enhanced by up to 35%. The inclusion of cenosphere improves the mechanical characteristics of composites by up to 5% by weight. The incorporation of filler to composite material improves water absorption resistance. As the weight percentage of jute fiber added, the thermal conductivity of these composites decreases. The use of cenosphere filler reduces the thermal conductivity of these composites. The inclusion of 0 to 10% filler reduces heat conductivity by roughly 9%. The thermal conductivity estimates derived from the inverse ROM model analysis match the testing well [2]. The analysis of variance revealed that jute fiber inclusion and waste plastic inclusion were the most influential variables. The best amounts of water absorption include 10% jute fiber furthermore 30% waste plastic expansion and treating the fibers with 10% sodium hydroxide concentration.

The inclusion of fiber content increased the mechanical characteristics of the composite specimens by up to 20%. However, increasing the amount of fiber weight resulted in a decrease in mechanical characteristics. Among the composites evaluated, the sample with 20% *Prosopis juliflora* fiber and Al_2O_3 filler had the best mechanical properties, with gains in tensile, flexural, and impact strengths of 7%, 11%, and 37%, respectively, above the composite without filler. Scanning electron microscope testing demonstrated that the particulates were equally disseminated inside the matrix, leading to the improved mechanical characteristics [3].

Materials and Method

Materials

Jute fiber (Figure 1a), coir fibers (Figure 1b), and glass (Figure 1c) are obtained from Go-green fiber Chennai purchased for this study. Jevanthee Enterprise Chennai provides epoxy resin, Araldite LY556, and Hardener HY951. The nano-filler Al_2O_3 was supplied by Ad-Nano Technologies Pvt. Ltd., of Shivamogga, India (Figure 2).

Preparation of resin

In this study, an ultrasonic probe sonicator was utilized to create the altered epoxy resin containing Al_2O_3 at 1%, 2%, and 3% by weight. To guarantee greater dispersal of Al_2O_3 into the epoxy resin, the necessary amount of Al_2O_3 (wt.%) was added to a different beaker and permitted to vibrate for 3 h in the ultrasonic probe sonicator. The same mix was also permitted to vibrate for 2 h in the rotary shaker. The epoxy and hardener have been combined and well blended at a 10:1 ratio.

Figure 1: (a) Coir fiber, **(b)** Jute fiber, and **(c)** Glass fiber.

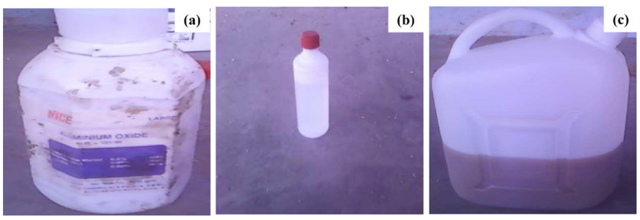

Figure 2: (a) Al_2O_3, **(b)** Hardener, and **(c)** Epoxy resin.

Fabrication of composites

The coir and jute fiber manufactured in the preceding procedures were placed on the previously specified mold. The epoxy resin-hardener combination was carefully filled over the coir and jute fiber after they were placed in the mold. Because of its small weight and large volume, coir and jute fiber swells. Only for this reason do we softly roll a roller until the specimen fits into the mould. The specimen is then covered with a non-reacting plastic cover, and the glass is placed on top, leaving no holes or air spaces. The sequence is made as per table 1. These voids damage the composite and complicate testing. Weight should be properly placed above the composite for it to be of precise dimension (Figure 3).

Tensile strength

The specimen tensile strength was manufactured in accordance with the ASTM D3039 (ASTM Standard D3039) standard, and the tensile test was carried out on it (Figure 4). The composite tensile strength and modulus were ascertained using an all-purpose testing instrument (INSTRON 3382). An experiment was carried out in accordance with ASTM D3039 specifications.

Flexural testing

The ASTM D790 standard utilized to conduct the flexural testing. The crosshead moved at a rate of 2 mm/min (Figure 5).

Impact testing

The ASTM D 256 standard utilized for the impact test, and the strip's measurements were 65 x 12.7 mm. The Charpy impact test machine was utilized in accordance with the specifications in Figure 6.

Table 1: Various compositions of composites.

Specimen	Al_2O_3 filler %	Resin	Fiber-filler %
G/J/C/C/J/G	0	60%	40%
G/J/C/C/J/G	1	60%	40%
G/J/C/C/J/G	2	60%	40%
G/J/C/C/J/G	3	60%	40%
J/C/G/G/C/J	1	60%	40%
J/C/G/G/C/J	2	60%	40%
J/C/G/G/C/J	3	60%	40%

Figure 3: Hybrid composite materials.

Results and Discussion

Tensile strength

The samples for tensile tests were carefully cut from the lamination with a band saw and trimmed to exact size using emery paper. Tensile testing was performed using a universal testing equipment in accordance with ASTM Standard D3039. Figure 7 shows the tensile behavior of composite

Figure 4: Ultimate tensile testing machine.

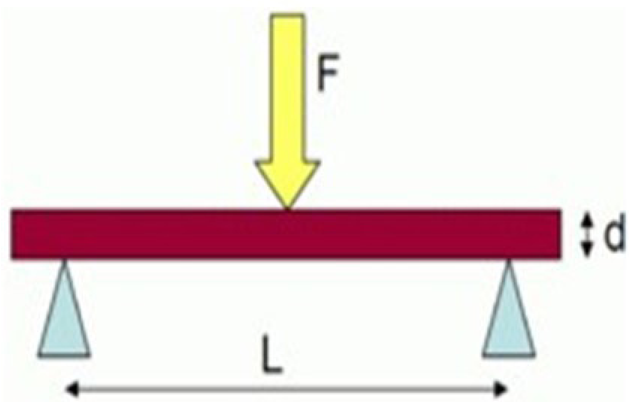

Figure 5: Flexural 3-point bending test.

Figure 6: Impact testing.

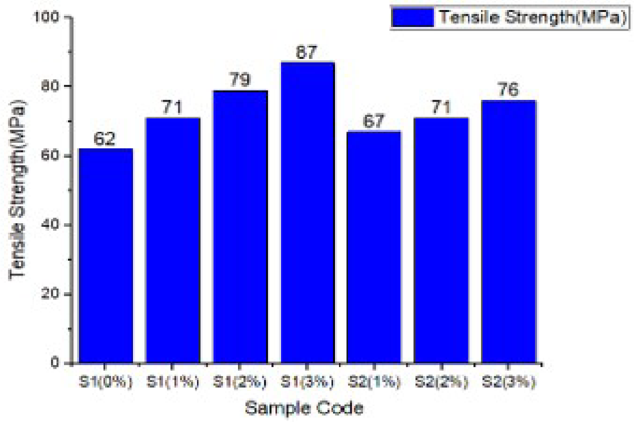

Figure 7: Tensile strength of the composite.

sample. Tensile strength reaches a maximum of 87 MPa for the specimen G/J/C/C/J/G with 3% Al_2O_3 addition, followed by 79 MPa for G/J/C/C/J/G with 2% Al_2O_3 addition. Tensile strength is enhanced by up to 22% when 3% Al_2O_3 composites are used instead of 0% Al_2O_3 composites for the stacking sequence of specimen G/J/C/C/J/G. The addition of 1% Al_2O_3 to the stacking sequence the sample J/C/G/G/C/J increases the tensile strength only up to 5.15%, and it is also noticed that the extreme plies of jute fiber reinforced composites at 3% Al_2O_3 show greater strength than the severe plies of coir fiber reinforced composites. Because of the high toughness and tensile characteristics of Al_2O_3, the tensile strength of the material improves as the weight percentage of Al_2O_3 increases as per the table 2 shown.

Flexural strength

The flexural strength of the hybrid composites is shown in figure 8. It should be observed that the laminated sequence G/J/C/C/J/G has elevated flexural strength when compared to the sequence J/C/G/G/C/J. The composite ability to withstand bending in a hybrid configuration was 118 MPa, increasing to 127 MPa in G/J/C/C/J/G composites. However, stacking glass as the outer layer and jute as the secondary layer increased the flexural strength of the G/J/C/C/J/G hybrid composites to 151 MPa. This demonstrated that using jute fiber as the glass reinforcement, jute and coir fiber as the inner layer resulted in a small increase in the flexural strength of the epoxy sample. As a result, altering the filler weight % in composite improves flexural strength.

Impact strength

The impact strength of a composite is the defiance it provides when subjected to high-speed stress. The specimens for the impact test are prepared in accordance with ASTM A-370. The energy required to shatter the material is measured during the test and represented in figure 9. The greatest impact strength measured for specimen G/J/C/C/J/G with 3% Al_2O_3 is 61 KJ/m^2. The impact value is improved by integrating the Al_2O_3 owing to the reinforcing action of the Al_2O_3 on the matrix phase in the sequence of G/J/C/C/J/G. Even though it enhances tensile strength in sequence J/C/G/G/C/J, it is 12.01% lower than in sequence G/J/C/C/J/G.

Table 2: Experimental test results.

Specimen	Al_2O_3 filler %	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
G/J/C/C/J/G	0	62	118	29
G/J/C/C/J/G	1	71	127	36
G/J/C/C/J/G	2	79	139	47
G/J/C/C/J/G	3	87	151	61
J/C/G/G/C/J	1	67	124	33
J/C/G/G/C/J	2	71	136	41
J/C/G/G/C/J	3	76	132	55

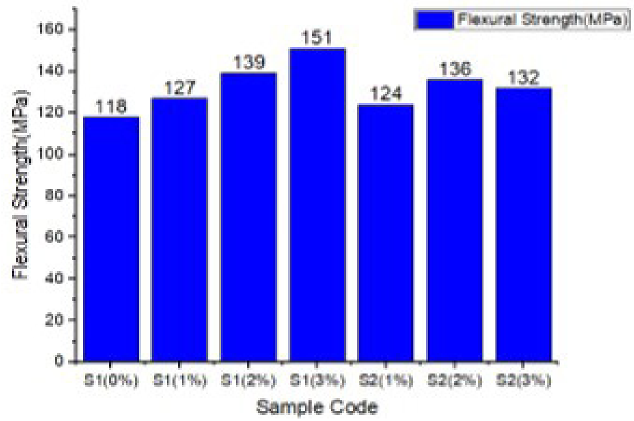

Figure 8: Flexural strength of the composite.

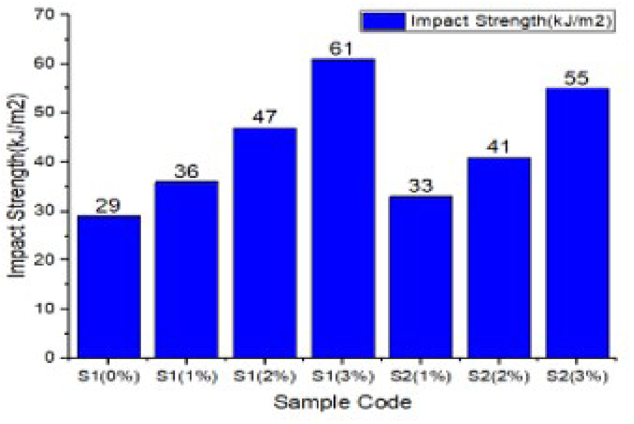

Figure 9: Impact strength of the composite.

Conclusions

- The percentage of Al_2O_3 nano-filler used has a beneficial impact on composite tensile strength. The tensile strength of the 3% Al_2O_3 nano-filler was 87 MPa.
- The flexibility of the composites improves as the amount of Al_2O_3 nano-filler increases. The bending strength of the 3% Al_2O_3 nano-filler was 151 MPa.
- When comparing to 0%, 1%, and 2% composition specimens, the composite sample with 3% Al_2O_3 nano-filler sustained a greater impact strength of 11.2 J.
- The tensile strength of the sample with 3% Al_2O_3 nano-

filler arose by 28.53% as compared to the specimen with 0% Al_2O_3 nano-filler.

- The specimen with 3% Al_2O_3 nano-filler has a 23.78% improvement in bending strength when compared to the specimen with 0% Al_2O_3 nano-filler.
- The sample with 3% Al_2O_3 nano-filler has a 6% higher impact strength than the specimen with 0% Al_2O_3 nano-filler.
- As a consequence, the mechanical properties of the 3% Al_2O_3 nano-filler specimen are higher in terms of tensile, bending, and impact.

Acknowledgements

None.

Conflict of Interest

None.

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