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Effect of Alumina Nano-filler in Glass/Hemp/Jute Reinforced Composite

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Abstract

The researchers looked at the mechanical properties of glass, jute, and hemp fiber reinforcing composites with aluminum oxide (Alumina) particles. The combination of alumina and jute fiber, as well as glass and hemp fiber, provided significant possibilities for changing the epoxy matrix. The fabrication of the composites was carried out using a manual hand lay-up technique, with the glass, jute, and hemp fiber volume fractions held constant at 20%, 10%, and 10%, respectively, with the alumina particle percentage ranging from 1 to 4 wt.%. When compared to the fiber reinforcement epoxy without alumina, the findings showed considerable improvements in different mechanical parameters. However, increasing the alumina particles to 4 wt.% resulted in even greater gains in mechanical characteristics. A few parameters, including tensile strength, flexural strength revealed a reversal in the enhanced trend when the alumina content was raised to 4 wt.%, despite the general favourable trend in mechanical property increases brought on by the inclusion of alumina particles.

Keywords

Alumina, Nano-filler, Epoxy, Hybrid nanocomposite

Introduction

Polymer matrix composites reinforced with fibers have acquired substantial attention and appeal in recent years when evaluated to other metal matrix composites. This is mostly owing to great specific strength and outstanding durability [1]. Natural fibers like jute, sisal, kenaf, and others are utilized as reinforcements in polymer composites as result of their ability to offer a favorable combination of high specific strength, eco-friendly characteristics, and easy availability from abundant sources. In recent times, there has been a growing fascination with the utilization of both synthetic and natural fibers for reinforcement purposes. The resultant hybrid composite materials have a unique mix of properties. The incorporation of fillers in polymeric composites has aroused the interest of analysts because of the superior static, dynamic, thermal, flame-retardant, and gas barrier characteristics of the resultant composites. Nano-fillers emerged as a viable option in the attempt to enhance the mechanical properties of fiber-reinforced polymer composites. Researchers took notice of their advantageous characteristics, such as adaptability to polymeric matrix, less cost and surface qualities. As research progressed, it became clear that the efficacy of these nano-fillers was dependent on characteristics such as their kind, size, shape, and the composition of the link formed among the matrix and the fillers.

The incorporation of 0.75 weight percent carbon nanofibers (CNF), nanoclays, (Montmorillonite (MMT), and organically modified montmorillonite (OMMT)) to a 40 wt.% kenaf fiber loading led to the manufacture of epoxy nanocomposites employing the hand lay-up method. In compliance with the findings, the inclusion CNF, MMT, OMMT made higher in mechanical characteristics of kenaf/epoxy composites. Furthermore, thermogram analyses revealed that the inclusion of CNF resulted in increased thermal stability and greater residual char content in kenaf/epoxy composites when compared to MMT hybrid nanocomposites. The inclusion of CNFs/MMT/OMMT increased the glass transition temperature (Tg) of kenaf/epoxy composites significantly [2]. Researchers used Taguchi design to investigate the water intake of composites with varied degrees of fiber and particle additives. They were able to identify the important characteristics influencing water intake thanks to the variance analysis. The inclusion of jute fiber and waste plastic greatly altered water uptake, according to their findings. The lowest levels of water absorption were obtained with 10% jute fiber inclusion, 30% waste plastic inclusion, and treatment is made for the fibers 10% sodium hydroxide concentration. This discovery has a high potential for wider use since it encourages the reuse of waste plastics in particle form, hence reducing their negative environmental effect. The hardness of the composites varied very slightly depending on the layer arrangement, and the mechanical performance of the hybrid composites was found to be comparable to that of the pure hemp composite. The hemp/jute/hemp combination had the maximum tensile strength of 66.34 MPa among the hybrid composites, and a similar were found in the flexural data. Mechanical experiments outcomes that adding hemp fiber as the outermost layer and jute fiber as the core layer can enhance the composites' tensile and flexural strength. However, it was discovered that this hybridization would result in a decrease in inter laminar shear strength. Novel fiber-reinforced polymer composites were created using the pultrusion technique by combining carbonized eggshell ash filler with jute and glass fiber roving's as hybridized fibers and unsaturated polyester resin as the matrix material. Eggshell ash powder used in various weight percentages that ranged from 3.5 wt.% to 15.5 wt.%. The wear behavior of these composites was studied with a pin-on-disc tribometer under two different load circumstances (30 N and 50 N), with the sliding distance, sliding speed, and track diameter held constant at 2 m/s, 1500 m, and 60 mm, correspondingly. The hybrid composites with 9.5 wt.% and 3.5 wt.% carbonized eggshell filler displayed the highest and lowest tensile strengths, measuring 85 MPa and 64 MPa, correspondingly. According to the findings, raising the total number of basalt fiber layers in the epoxy-based hybrid composite lead to a greater tensile modulus. The tensile modulus was maximized when 6 layers of basalt fiber were mixed with jute enforced epoxy composite. Similarly, adding basalt fiber into the jute-based epoxy composite resulted in a significant improvement in tensile strength. As the quantity of basalt epoxy layers stacked increased, there was a notable enhancement in the compressive modulus and compressive strength of the composite. The study provided a detailed analysis of the experimental data by presenting response tables for signal-to-noise ratio and means. The load was shown to have the greatest impact on the specific wear rate, followed by the kind of sample and density. The study considered two different combinations of compositions, namely Cobalt (Co) + glass fiber (GF) and Co + carbon fiber (CF). The study indicate that the flexural and tensile strength of the material exhibited significant improvements compared to specific composite materials. Notably, when 35% of GF or CF was added to the epoxy resin along with 0.6 wt.% of Co content, substantial enhancement in tensile and flexural strength were observed. The tensile strength recorded on the universal testing machine Model AG-KNISMS/130,104,504,279 machine was 96.670 MPa for GF and 193.23 MPa for CF, while the flexural strength reached 112.465 MPa for GF.

The flexural and compressive properties of the TSPF/GF/epoxy composites were found to be superior in comparison to the UTSPF/GF/epoxy composites. Incorporating GF into the SPF composites resulted in significant enhancements in both flexural and compressive properties, and higher GF content further improved these properties. The composite with a 30 TSPF:70 GF ratio exhibited the highest flexural and compressive properties among the SPF/GF/epoxy hybrids. Scanning electron microscopic analysis also confirmed the improved flexural and compressive properties of the 30TSPF:70 GF hybrid composite. Additionally, these hybrid composites showed comparable properties to pure GF composites, indicating the effectiveness of combining TSPF and GF in the hybridization process. The study investigates the strength of mechanical properties of hybrid composites, incorporating parameters like red mud size (4 and 13 μm) and weight percentages (2, 4, 6, and 8 wt.%). The experimental findings demonstrate that the inclusion of red mud positively impacts the mechanical traits of the hybrid composite. Introducing red mud particles to the sisal/glass composite boosts tensile strength by 33% and flexural strength by 54%. Moreover, the incorporation of red mud enhances the impact strength of the sisal/banana composite by 25%. To predict deviations in data scatter plots, linear regression analysis is employed, aiding in establishing correlations among different variables. Additionally, scanning electron microscopy is utilized to explore how red mud affects interfacial bonding in polyester composites reinforced with banana/sisal and sisal/glass fibers. [3].

Materials and Method

Materials

Jute fiber (Figure 1a), hemp fibers (Figure 1b), and GFs (Figure 1c) were obtained from Go-green fiber Chennai for this study. Araldite LY556 epoxy resin and Hardener HY951 hardener were acquired from Jevanthee Enterprise Chennai. Ad-Nano Technologies Pvt. Ltd., based in Shivamogga, India, provided the nano-filler alumina utilized in the study (Figure 2).

Fabrication technique

To obtain a consistent distribution of particles, alumina is incorporated to the epoxy resin and manually stirred. Each

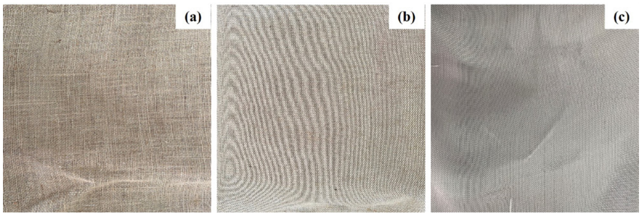

Figure 1: (a) Jute fiber, **(b)** Hemp fiber, and **(c)** Glass fiber.

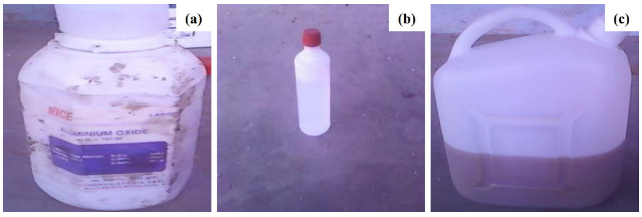

Figure 2: (a) Alumina, **(b)** Hardener, and **(c)** Epoxy resin.

hemp, glass, and jute fiber mat are appropriately proportioned and set in a mould with overall dimensions of 300 mm x 125 mm x 3 mm. The epoxy/alumina combination is eventually poured into the mould, and then closed for 1 day to cure at ambient temperature. The same method is used to create hemp, glass, and jute composites. In the trials, various weight fractions of alumina (1, 2, 3, and 4 wt.%) are utilized.

Tensile and flexural testing (ASTM D 638) are performed on a universal testing machine (Figure 3 and figure 4), whereas impact strength (ASTM D 256) is determined using a Charpy impact tester (Figure 5).

Results and Discussion

Tensile strength

The sample with various weight % of alumina composite specimen are examined and the findings are visually represented on the graph. The tensile strength of jute, glass and hemp with 0%, 1%, 2%, 3%, and 4% alumina composite are in between of 128 MPa and 179 MPa correspondingly and table 1 represents the sequence and weight percentage. The results indicate that among the various composite combinations, the one involving glass, jute, and hemp with a 4% alumina content exhibits superior tensile strength are shown in figure 6. This can be attributed to the elevated tensile strength of alumina as well as the strong bonding between the fibers and the matrix. Furthermore, when the particles are added above 4% of alumina the tensile strength reduced. Higher the filler content might result in poor adherence at the filler-matrix interface. Under stress, a weak interface allows the filler to readily deboned from the matrix, limiting the efficacy of load transmission through the filler and matrix. As a result, the composite tensile strength is compromised. Table 2 represents experimental result.

Flexural strength

The findings suggest that as the weight percentage of alumina is raised, the composites' ability to bear flexural loads experiences an increase. The highest flexural load 274 MPa is obtained for jute, glass and hemp fiber composite integrate with 4% (wt.%) of alumina followed by 261 and 247 for 3% and 2% (wt.%) integrate alumina, individually. Flexural strength is

Figure 3: Ultimate tensile testing machine.

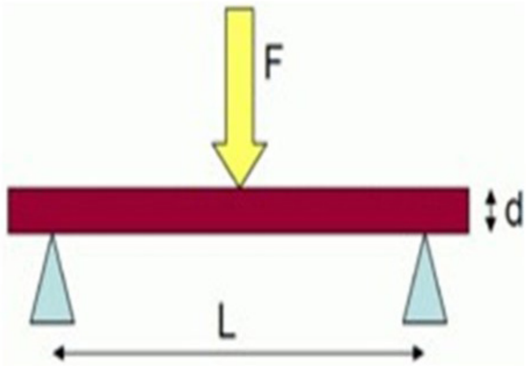

Figure 4: Flexural 3-point bending test.

Figure 5: Impact testing.

Table 1: Various compositions of composites.

Specimen	Alumina filler %	Resin	Fiber %
S1	0	60%	40%
S2	1	59%	40%
S3	2	58%	40%
S4	3	57%	40%
S5	4	56%	40%

enhanced by up to 18.36% when 4% alumina composites are used instead of 0% alumina composites are shown in figure 7. The data demonstrates that the composite containing 4% alumina is more adept at withstanding bending loads when

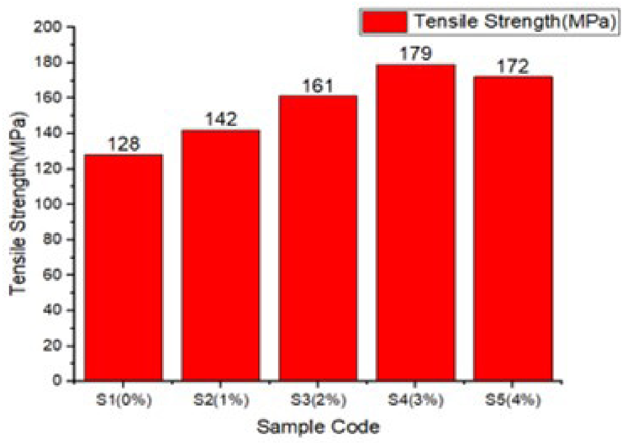

Figure 6: Tensile strength of the composites.

Table 2: Experimental test results.

Specimen	Alumina filler %	Tensile strength (MPa)	Flexural strength MPa)	Impact strength (KJ/m²)
S1	0	128	231	64
S2	1	142	247	72
S3	2	161	261	81
S4	3	179	274	93
S5	4	172	259	84

compared to composites with lower alumina concentrations of 3%, 2%, and 1%.

Impact strength

The impact strength of a composite is the resistance it provides when subjected to high-speed stress. The sample for the impact test is done in accordance with ASTM A-370. The energy required to shatter the material is measured during the test and represented in figure 3. The greatest impact strength measured for specimen 4 with 4% alumina is 93 kJ/m^2. The impact value is improved by integrating the alumina owing to the reinforcing action of the alumina on the matrix phase in S4 are shown in figure 8. Even though it enhances impact strength in S4, S5 is reduced due to filler particles may begin to agglomerate and form clusters at high filler loadings. These clusters not only cause voids in the composite, but they also obstruct appropriate load transmission from one filler particle to the next and from the filler to the matrix. Impact strength is diminished due to poor load transmission.

Conclusion

A successful polymer composite made of jute, glass, and hemp fibers, epoxy resin, and alumina nanoparticles has been created by hand lay-up process. The result examined the effects of filler content on the mechanical properties of glass, jute, and hemp fiber epoxy composites and discovered that adding 3 wt.% of filler to the matrix improved the mechanical characteristics of the polymer composites. In 4% of filler the mechanical strength reduced due to the matrix's diminished capacity to deform and absorb energy, a composite with a larger filler content may become more brittle. Premature failure under tension may result from the material's lack of

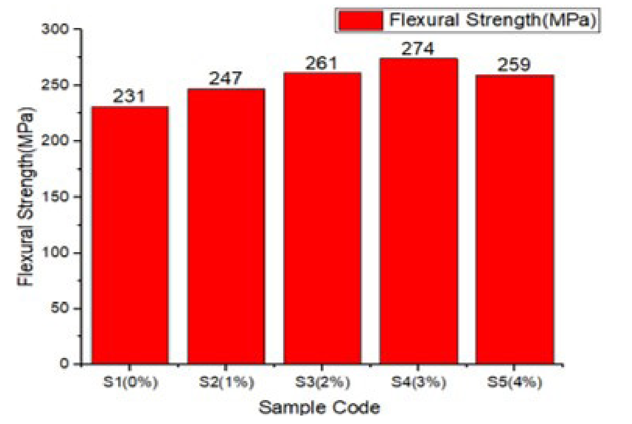

Figure 7: Flexural strength of the composites.

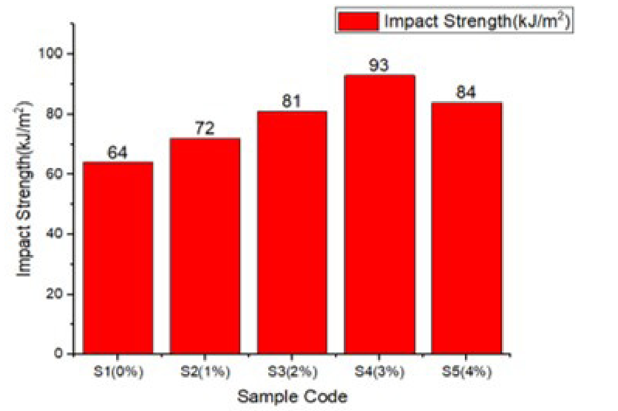

Figure 8: Impact strength of the composites.

ductility and toughness. The ability of the filler to uniformly transmit and disperse stress from the continuous matrix phase to the dispersed fiber phase leads to a heightened collective strength, can be credited with the improvement in mechanical properties. Alumina was used as a nano-filler, and its presence had a notable impact on the composite system mechanical characteristics.

Acknowledgements

None.

Conflict of Interest

None.

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