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Enhancing Mechanical Properties of Fiber-Reinforced Composites Through Sorghum Husk and Unsaturated Polyester Resin

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Abstract

Plastic, a versatile synthetic polymer, holds considerable significance and utility in human society due to its manifold applications. However, its deleterious ecological ramifications have spurred growing apprehensions. This has galvanized the pursuit of ecologically amicable substitutes, propelling interest in the domain of composite materials. Composites are formulated by amalgamating diverse substances, and in this context, Styrene Diluted Unsaturated Polyester Resin (SDUPR) is melded with natural constituents. Among these organic constituents, Sorghum Husk is the subject of scrutiny in this inquiry. The formulation of these composites entails a multiplicity of methodologies, encompassing Spray-Up, Pultrusion, Manual Layup, Automated Layup, and Resin Transfer Molding. In this specific examination, the manual layup technique is harnessed. The procedure encompasses the fabrication of sheets with varying proportions of Sorghum Husk and SDUPR, concomitant with the inclusion of a curing agent to expedite solidification. In this study, four distinct composite sheets are engendered, distinguished by Sorghum Husk to SDUPR ratios of 50:50, 55:45, 60:40, and 65:35. The performance appraisal of these composite sheets is effectuated through a battery of evaluations. These encompass the Flexural Test, quantifying material flexural potency; the Izod Impact Test, assessing material tenacity; the Rockwell Hardness Test, appraising material resistance to indentation; and the Biodegradability Test, measuring the material's intrinsic degradation process. Hardness and biodegradability profiles evince fluctuations in tandem with the manipulation of Sorghum Husk and SDUPR ratios. Comparative scrutiny among the four sheets accentuates the mechanical property modulations as the equilibrium between Sorghum Husk and SDUPR is transmuted. The revelations evince that an upswing in Sorghum Husk concentration begets a decrement in mechanical attributes such as pliancy, hardness, and impact resilience. Additionally, the biodegradability of the composite substrate dwindles with augmented Sorghum Husk proportions. Fundamentally, this inquiry elucidates the intricate interplay between Sorghum Husk and SDUPR ratios and the ensuing composite material traits. The findings underscore the inherent compromises in optimizing both mechanical efficiency and environmental imprint, furnishing invaluable insights into the evolution of sustainable composite materials.

Keywords: Biodegradability, composites, hardness, sorghum husk, polyester resin

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INTRODUCTION

Waste products that are harmful to the environment is a problem in today's globe. Numerous studies have been carried out to create materials that are safe to use in environmental concerns and have good features. In contrast to synthetic fibers, materials with natural fibers are gaining interest for a variety of mechanical applications. Natural fibers are mostly sourced from plants and animals. Plants which have fibers on their stem like Bamboo, flex, stinging nettle, jute, kenaf, hemp etc. can be used as fillers instead of synthetic fillers [1-4]. Lower shrinkage qualities, environmental resistance, water resistance, strong electrical insulation, binding strength, and improved chemical resistance are all advantages of polyester polymers. Additionally, because unreinforced polymers have lower toughness and impact strength, they display less resistance to shearing. As a result, reinforcement delivers enhanced mechanical qualities, increased wear resistance, reduced vibration, and increased load carrying capability [5-8]. Unsaturated polyester resin, which is frequently used as the matrix in artificial glass fiber composites, has been modified to make it more compatible with cellulose fiber [9-11]. Unsaturated and saturated acid/anhydrides and diols or oxides undergo a linear polycondensation reaction, which results in the formation of unsaturated polyester resin. The Resins are made of oligomers that are pale yellow in color and have very little polymerization. The chemical composition and molecular weight (between 1200 and 3000 g/mole) of the oligomers determine whether they are viscous liquids or brittle solids. The Unsaturated Polyester Resins are widely used throughout the world due to its versatility, and low cost [12].

The current research involves creating composites out of Sorghum husk and unsaturated polyester resin. These composites can be used for a variety of purposes and have improved mechanical qualities, waste reduction, lightweight construction, cost-effectiveness, environmental advantages (biodegradability), and thermal insulation. The results showed that the filler treatments enhanced the mechanical properties and reduced water absorption by increasing the interfacial adhesion between the fibers and matrix. In light of this, the created composites make excellent alternatives for a range of prospective applications. It's crucial to keep in mind that the precise characteristics and functionality of the composite will depend on elements like the composition ratio of sorghum husk to resin, the manufacturing process, and any other additives or treatments used.

In this research, a natural composite of resin was produced using sorghum husk as a sustainable filler raw material. Sorghum was initially crushed and converted into powder form, after which they were mixed with 1% Benzoyl peroxide as a curing agent in a glass beaker. Before adding Styrene Diluted Unsaturated Polyester Resin (SDUPR), the mixture was well swirled with a glass rod. Stirring was continued until a homogeneous mixture free of lumps was created. Two iron plates, each measuring 260 mm x 260 mm with a thickness of 12 mm, were chosen. These plates were equipped with four holes at their four corners, and a Teflon sheet measuring 180 mm x 180 mm was placed on each plate. The mixture was used to make a laminate that was 9 mm thick and 150 mm × 150 mm in size. This laminate was placed on one of the iron plates above the Teflon sheet. The laminate was covered with a second Teflon sheet of the same size, which was then topped by a second iron plate and all four corners of the plates were then fixed with nuts and bolts. The material was then heated in an oven set at a temperature of 100^0C for two and a half hours. Subsequently, the oven was turned off, and the material was left to rest in the oven for 24 hours. After removal from the oven, a natural composite of resin was obtained (Figure 1). Four different sheets were prepared, with variations in the amount of sorghum husk powder and SDUPR (Table 1). However, the proportion of the curing agent (Benzoyl Peroxide) was kept constant, representing 1% of the total weight of the mixture [12-14].

Materials and Methods

In this procedure, a pivoting arm is raised to a certain height and then released, measuring the material's impact resistance. An arm swings downward, striking the notched sample and breaking it. For instance, the impact energy for the 50:50 mixture is 1.85 J/cm^2, whereas for the mixtures of 55:45, 60:40, and 65:35, the impact energies are 1.70 J/cm^2, 1.64 J/cm^2, and 1.51 J/cm^2, respectively. Figure 2 shows the relationship between the proportion of sorghum husk and impact energy. The trendline shows a gradual decrease in impact energy as the proportion of sorghum husk increases.

RESULT AND DISCUSSION

The Rockwell Hardness test measures the permanent depth of indention produced due to force of an indenter. Different kinds of scales with a single letter designation that employ various loads and

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indenters. The Rockwell Hardness test uses a variety of indenters, including diamond, 1/16" ball, 1/8" ball, 1/4" ball, 1/2" ball, etc. Sorghum husk sheets are tested for hardness using the HrA scale, with a preload of 60 kg. The hardness of carbides, thin steel, shallow case-hardened steel, etc. is also measured using this scale. the hardness unit expressed in kg/mm. Figure 3, is evident that the hardness of the material gradually decreases as the proportion of sorghum husk increases.

Figure 1. Composite of sorghum husk and SDUPR.

Table 1. Proportion of Sorghum Husk and SDUPR.

S N.	Particular	PSS-1	PSS-2	PSS-3	PSS-4
1	Amount of Sorghum husk	100 gm	110 gm	120 gm	130 gm
2	Amount of SDUPR	100 gm	90 gm	80 gm	70 gm
3	Total Weight of Mixture	200 gm	200 gm	200 gm	200 gm
4	Amount of Benzoyl Peroxide	2 gm	2 gm	2 gm	2 gm
5	Ratio (Sorghum husk: SDUPR)	50: 50	55: 45	60: 40	65: 35

SHS-1= 50:50, SHS-2= 55:45, SHS-3= 60:40, SHS-4= 65:35

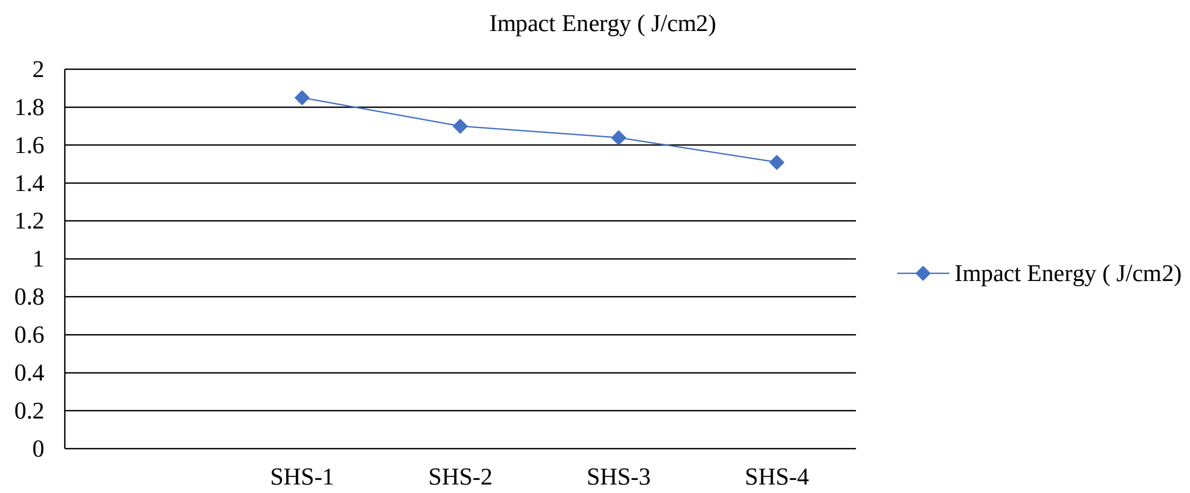

Figure 2. Impact energy.

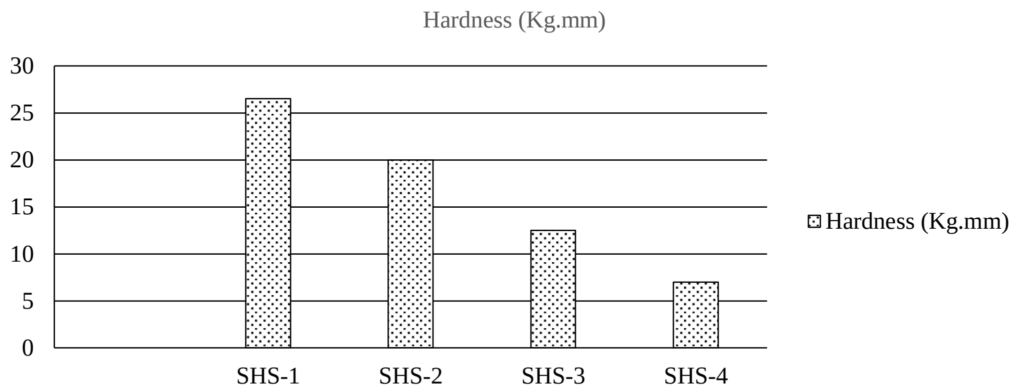

Figure 3. Hardness.

Table 2. Flexural strength test.

Ratios sorghum husk: resin	Width (mm)	Thickness (mm)	Stiffness (N/m)	Young's modulus of bending (Mpa)	Load at maximum load (N)	Flexural rigidity (Nmm2)	Work from preload to maximum extension (Nmm)	Preload (N)	Preload speed (mm/min)
SHS-1	11.15	6.41	32150.08	3343.05	30.32	774268.28	55.40	0.5	2
SHS-2	11.51	6.85	28268.37	2508.05	24.35	579084.28	44.84	0.5	2
SHS-3	10.66	7.16	23512.87	1042.85	19.25	367903.96	35.69	0.5	2
SHS-4	10.62	7.25	17496.24	838.60	11.17	179791.76	24.32	0.5	2

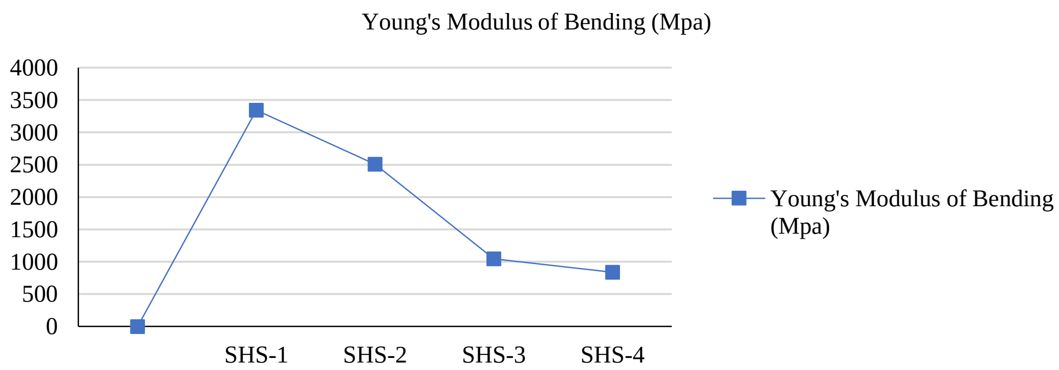

Figure 4. Young's modulus of bending

The flexural test evaluates the quantity of force required to bend a plastic beam and assesses the material's stiffness or resistance to bending. Flexural modulus demonstrates how far a material can bend without permanently changing its shape. The key factors that determine a material's flexibility are its Young's modulus of bending and flexural Rigidity The flexural test is a technique employed in the field of materials science and engineering to quantify the bending strength of a plastic beam and assess the material's stiffness or resistance to bending. The flexural modulus is a parameter used to gauge the material's capacity to bend without experiencing permanent deformation. The principal factors governing a material's flexibility are its Young's modulus of bending and flexural rigidity. Based on the data represented in Figure 4, it can be observed that there is a minor reduction in the measured parameter between SHS-1 and SHS-2, a substantial decrease between SHS-2 and SHS-3, and a minimal decrease between SHS-3 and SHS-4. Figure 5 indicates a correlation between the increasing proportion of peanut shells in the material and a continuous decline in flexural rigidity. This observation implies that a decrease in resin proportion leads to a reduction in both flexibility and flexural rigidity of the material.

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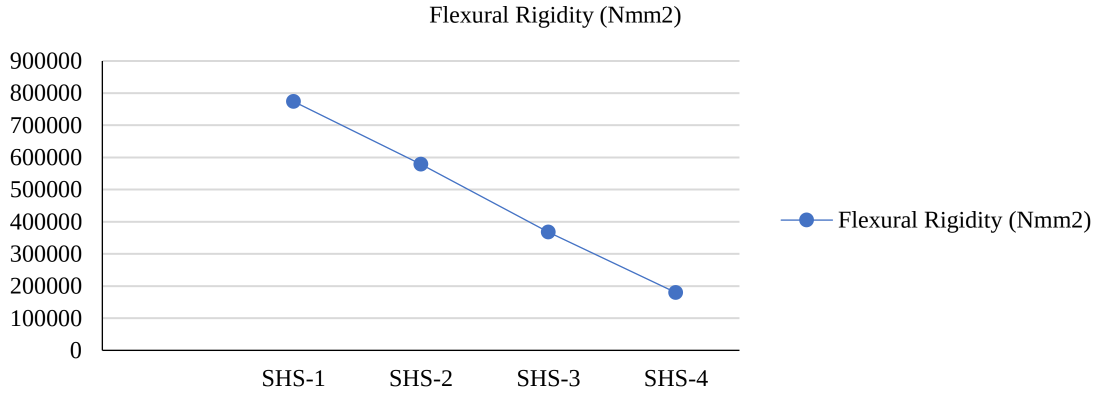

Figure 5. Flexural rigidity.

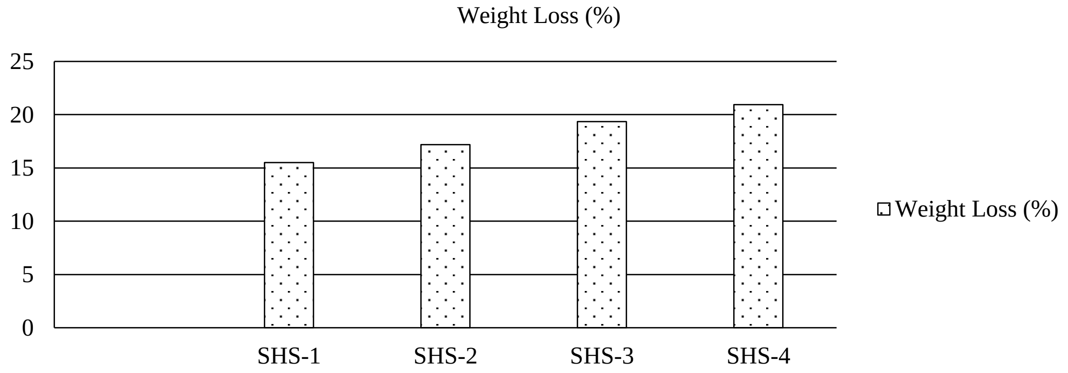

Figure 6. Biodegradability.

Biodegradability is a very important parameter. It is measured for 30 days cycle and the weight loss noted carefully. The test is conducted using four different samples each with dimensions of 10mm x 15mm. The samples have different ratios of sorghum husk and Resin initiated, which are 50:50, 55:45, 60:40, and 65:35 and these samples are pre-weighed. To conduct the test, four conical flasks are used, each containing 100 ml of Sabouraud solution. The flasks are inoculated with Aspergillus fungus. Optical Density (O.D.) is measured at 600nm at interval of 24 hours to track the growth of the fungus and O.D. is measured until the growth of fungus stops and to measure the sugar released, the DNSA method is adopted. After 30 days, all samples are removed and dried properly. Their weights are measured, and the weight loss of each sample is calculated. The results show that as the proportion of sorghum husk in the samples increases, biodegradability also increases. It is observed by Figure-6 that the biodegradability is maximum when the ratio for sorghum husk and Resin is 65:35. This experiment also indicates that when the proportion of Resin is increased, biodegradability decreases.

Applications

Composites made of Natural Fibers combined with unsaturated polyester resin have gained significant attention in recent years due to their unique properties and environmentally friendly nature. These composites find applications in various industries, including automotive, aerospace, construction, and consumer goods. Natural fiber composites with unsaturated polyester resin are being increasingly used for manufacturing automotive parts, such as interior trim panels, door panels, seat backs, and parcel shelves. Composites being used in the sports and recreation industry for manufacturing equipment such as bicycles, skateboards, and helmets. These composites are ideal for automotive applications because of their superior mechanical characteristics, which include high strength and stiffness, low weight, and outstanding impact resistance. These composites are appealing for use in consumer goods because they have distinctive characteristics such natural beauty, light weight, and biodegradability [15-18].

CONCLUSION

The synthesis of novel materials for innovative applications represents a prominent and pressing scientific and technological challenge in today's world. The properties of composite materials, as well as their interactions with the matrix, are influenced by the concentration, ratio, and reinforcement content of fillers, reinforcements, and modifications. To evaluate the performance of the hybrid composites produced, investigations were conducted on the changes in mechanical characteristics with varying content and volume ratios of the fabrics. While there are limited studies on miscible polyester resin polymer blends, the scientific literature on this subject is steadily expanding. Unsaturated polyester resins, due to their low production costs and high tensile strength, have been extensively employed as significant thermosetting polymers in the industry. This research focuses on four distinct sheets of composite materials, combining Sorghum Husk and SDUPR at different ratios. It has been observed that an increase in the proportion of Sorghum Husk leads to a decline in mechanical properties, as evident from Rockwell Hardness Test, Izod impact test, Flexural test, etc. Additionally, the Biodegradability test reveals that as the content of Sorghum Husk increases, biodegradation also increases.

Based on the data from the chart on Sorghum Husk to Resin ratios and their corresponding Impact Energy (J/cm2) at a fixed Impact Angle of 144 degrees, it can be concluded that Impact Energy decreases as the Sorghum Husk to Resin ratio decreases. SHS-1 with the highest ratio exhibits the highest Impact Energy (1.85 J/cm2), while the Impact Energy decreases sequentially for SHS-2, SHS-3, and SHS-4. The comparison of SHS-1 to SHS-4 indicates that higher Sorghum Husk to Resin ratios lead to higher Impact Energy, while lower ratios result in lower Impact Energy. The fixed Impact Angle of 144 degrees does not significantly influence the variations in Impact Energy. From the data on Sorghum Husk to Resin ratios and their corresponding Hardness values, it can be observed that the hardness of the material decreases with decreasing ratios. SHS-1 with the highest ratio has the highest hardness value (26.50 Kg.mm), while SHS-4 with the lowest ratio exhibits the lowest hardness value (7.00 Kg.mm). The relationship between the ratio of Sorghum Husk to Resin and Hardness appears to be inversely proportional, with lower ratios leading to softer materials and higher ratios resulting in harder materials. Further analysis is needed to determine the optimal ratio for achieving a desired hardness.

Analyzing the data on the Young's Modulus of Bending (Mpa) for different samples of Sorghum Husk and Resin, it can be concluded that SHS-1 has the highest Young's Modulus of Bending (3343.05 Mpa), indicating greater stiffness or rigidity. SHS-4 has the lowest Young's Modulus of Bending (838.60 Mpa), making it the least rigid among the samples. SHS-2 and SHS-3 fall in between with intermediate stiffness values. The trends suggest that the Young's Modulus of Bending is directly related to the rigidity, with higher values indicating higher stiffness. Regarding the weight loss percentages, the data shows that as the ratio of Sorghum Husk to Resin increases, the weight loss percentage also increases. SHS-4 experiences the highest weight loss percentage (20.94%), while SHS-1 exhibits the lowest weight loss percentage (15.52%). The resin treatment led to decreased weights in all sorghum samples over the 30-day period, and the variations in weight loss suggest that the initial weight of the samples may influence the effectiveness of the treatment.

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