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Research Article

Experimental Studies on Mechanical and Thermal Properties of Polyester Hybrid Composites Reinforced with Sansevieria Trifasciata Fibers

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In the recent decades, natural fiber reinforced composite (NFRC) plays a vital role in most of the engineering applications including automobile and structural. The demand for novel natural fiber increasing steeply in recent times. Current research work aimed to develop hybrid sansevieria trifasciata fiber (HSTF)/polyester composite, and researchers combined untreated sansevieria trifasciata fibers (USTFs) with NaOH treated sisal fibers (NSTFs) and combined them with a polyester matrix. The reinforced effect of HSTFs was shown to be superior to that of NSTFs. It has the tensile strength of 48.47 MPa, the flexural strength of 69.17 MPa, and the impact strength of 16.34 kJ/m^2. The thermal behaviour of the composite increased because of chemical treatment and hybrid composition. Polyester/HSTFs show superior mechanical properties compared to other developed samples.

1. Introduction

Because of their superior mechanical properties and biodegradability, polyester and natural fiber composites have gotten a lot of attention. Polyester is a high-modulus, and high-strength polymer used as a matrix in most of the polymer-based composites [1, 2]. Natural fibers are environmentally friendly fibers derived from natural sources because natural fiber reinforced composites (NFRCs) are completely biodegradable in soil. In addition to that, NFRC has merits such as recyclability, low density, and cheap cost over man-made fibers [3]. NFRC is frequently used in automobile and structural parts due to its lower weight, biodegradable, and higher specific strength [4–7]. To increase fiber compatibility, certain techniques for pretreatment were applied, such as physical explosion, thermal treatment, chemical treatment, and so on [7, 8]. While these approaches improved matrix fiber bonding, enhancing the roughness of the surface, and the mechanical behavior (tensile, flexural, and impact strength). Even though chemical treatment enhances the matrix fiber bonding, it causes fibers to fracture rather than pull out when subjected to mechanical stress [9–11]. In the meantime, the hybrid composite of chemically treated and untreated sisal fiber-reinforced polylactic acid showed superior quality than the other composition [12]. Indran et al. [13] reported that a high NaOH concentration and a longer soaking time caused fiber degradation, disrupted fiber structure, and reduced fiber strength. Furthermore, following NaOH treatment, reduces the thickness of fiber due to the removal of hemicelluloses, lignin, and other contaminants [14, 15]. When the fiber penetrates into the polymer matrix, fracture strength is mainly depending on the fiber volume and length of the fiber. Generally, fibers predominantly exhibit the following failure mechanisms, namely, delamination, fiber pull-out, and fiber fracture [16, 17]. The cissus quadrangularis stem fiber (CQSF) has more physical and chemical properties. It has the cellulose content of nearly 82% [13]. Though it has adequate properties because of poor bonding the mean strength was not as much as expected. But, the treated cissus quadrangularis stem fiber (CQSF) reinforced polyester composite produced high tensile and flexural strength and also found minimum delamination while fracturing [18]. The thermal and tribological behaviour of the CQSF/Epoxy have been identified as good as compared to other composite materials [9]. It indicates that the thinner the fibers in the composite, the poorer the mechanical qualities. In this study, certain untreated sansevieria trifasciata fibers (USTFs) were combined with NaOH-treated sansevieria trifasciata fibers (NSTFs) to create hybrid sansevieria trifasciata fibers (HSTFs), which were then put into a polyester matrix to form polyester/HSTF composites. Sansevieria trifasciata fiber (STF) is derived from the leaf of the sansevieria trifasciata plant, which is abundantly farmed in South Asia.

The hybrid STFs reinforced polyester is a new composition for this fiber. It has not been done in any other studies. In this paper only, the performance analysis of HSTFs/polyester composite has been discussed. The plant of STFs was shown in Figure 1. Low density, high relative strength, and biodegradability are only a few of the benefits of STFs. The inclusion of USTFs was intended to reduce the drawbacks of fiber surface modification through chemical treatment and improve the performance of STF reinforced polyester composites, particularly mechanical properties.

Figure 1: Sansevieria trifasciata plant.

Table 1: List of prepared materials.

Sample code	Description	USTF (%)	NSTF (%)	Matrix (%)
Sample *A*1	USTF/ Polyester	30	0	70
Sample *A*2	NSTF/ Polyester	0	30	70
Sample *A*3	HSTF/ Polyester	15	15	70

2. Experimental Methods

2.1. Materials. Covaiseenu chemicals supplied the polyester. Table 1 lists the compositions of the prepared polyester composite material. Sansevieria trifasciata fibers were collected from the local region of Coimbatore district as in Figure 1, Tamilnadu, India. Table 2 shows the composition and mechanical parameters of sansevieria trifasciata extracted fiber. In NaOH Treatment of STFs, hemicelluloses, lignin, and other tiny molecular components in STFs may be removed by NaOH treatment. With a cutting machine, the STF is converted to short fibers (fiber length-40 mm). The STFs were then immersed in a 5% NaOH solution for the duration of 3 hours. Finally, NaOH treated STFs were cleaned with pure water and dried in the open air for 48 hours.

2.2. Sample Preparation. Polyester, NSTFs, and USTFs were all dried for 4 hours at 80°C. To make HSTFs, treated fibers were mixed with untreated fiber in the 1 : 1 ratio. The treated and untreated fibers are given in Figure 2. The polyester was poured and compounded with the STFs at room temperature. According to Table 1, three types of samples were created: polyester/USTF (A1), polyester/NSTFs (A2), and polyester/HSTFs (A3). The sample images showed in Figure 3. Temperature and pressure for compression moulding were 30°C and 10 MPa, respectively. For the tensile test, dumbbell-shaped specimens ($75 \times 4 \times 1$ mm, parallel portion 25 mm) were made, while rectangular specimens ($80 \times 10 \times 4$ mm) were prepared for the flexure and impact tests, respectively.

2.3. Mechanical Examination. The composites' tensile and flexural characteristics were tested with the aid of the Instron Universal Testing Machine (Instron: model-5565). An Izod Impact Tester was used to conduct the impact testing. The samples were prepared according to the ASTM standard for the comparison purpose [18].

2.4. Thermal Characteristics. A TGA was performed on the composites using a Thermogravimetric Analyser (model: STA 409) to determine their thermal stability. The sample used for this experiment is powder form and the temperature is raised by 10°C/min in presence of nitrogen gas. The maximum temperature for this experiment is 700°C.

2.5. Morphological Study. A scanning electron microscope was employed to examine the matrix fiber adhesion in the developed samples. The gold coating was used over the surface of the sample where the fracture took place. The gold coating increased the conductivity of the electron which means the image is very clear.

3. Results and Discussion

3.1. Mechanical Characteristics. Figures 4–6 show the mechanical properties of the developed samples. The tensile strength (32.53 MPa), flexural strength (61.42 MPa), and impact strength (11.42 KJ/m^2) of polyester/USTFs are reported, meanwhile, those of polyester/NSTFs are tensile

Table 2: Numerical results after the experiment.

Sample code	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Impact strength (KJ/m^2)
Sample *A*1	32.53	2.15	61.42	2.42	11.42
Sample *A*2	45.26	2.56	66.73	3.16	13.15
Sample *A*3	48.47	2.72	69.17	3.33	16.34

Figure 2: Extracted fiber with untreated and NaOH treated.

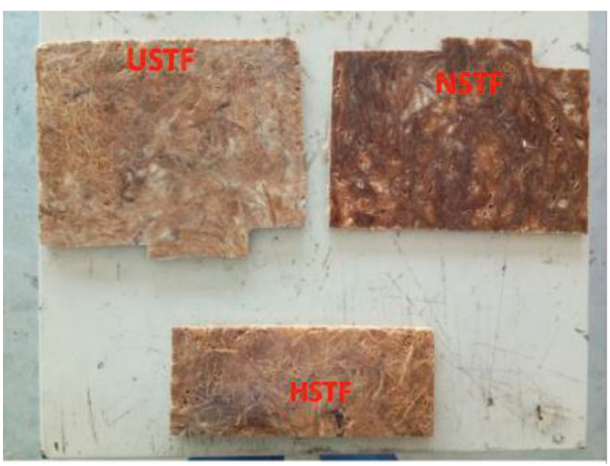


Figure 3: Prepared composite materials.

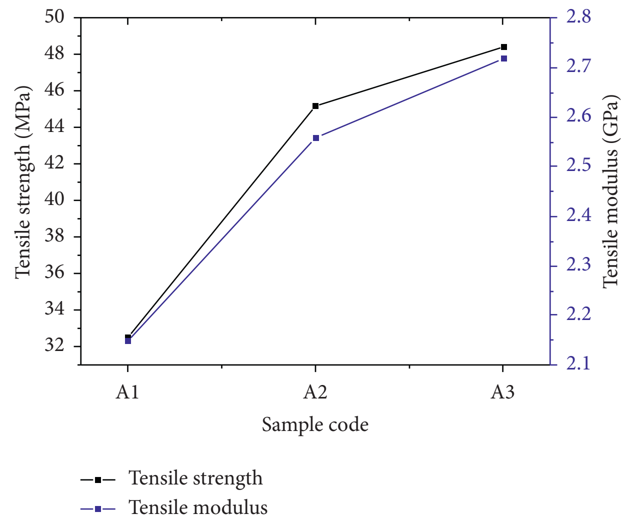


Figure 4: Tensile strength and modulus results.

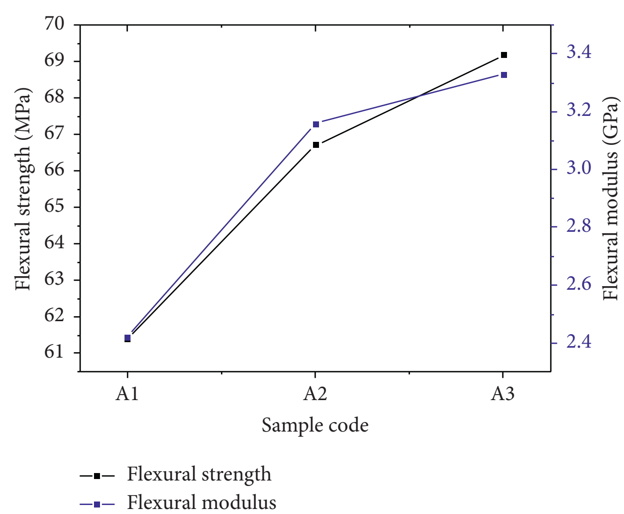


Figure 5: Flexural strength and modulus results.

strength (45.26 MPa), flexural strength (66.73 MPa), and impact strength (13.15 KJ/m^2), which are higher than neat polyester with USTFs. It demonstrates that polyester and NSTFs are compatible, as well as NSTF dispersion in a polyester matrix. The tensile and flexural modulus of the USTF sample are 2.15 and 2.42 GPa, whereas the tensile and flexural modulus of the treated sample shows 2.56 and 3.16 GPa, respectively, superior than the neat polyester with the USTFs sample. It might be because the modulus of STFs is superior than the plain polyester sample, or because the microstructure of polyester composites changes when STFs are added. As a result, further research into crystal morphology is required. Hybrid sample HSTF sample properties are good compared to other developed composites. The hybrid samples show flexural strength and modulus values of 69.17 and 3.3 GPa, respectively, which are 3.65% and 5.37% greater than polyester/NSTFs. Polyester/HSTFs have tensile strengths and moduli of 48.47 MPa and 2.72 GPa, respectively, which are 7.09% and 6.25% greater than polyester/NSTFs. The impact strength trends are also obtained, as illustrated in Figure 6. Polyester/HSTFs have 16.34 KJ/m^2 impact strength, which is 24.2% greater than polyester/NSTFs. There are three basic reasons why polyester/HSTFs have superior mechanical qualities than polyester/NSTFs. First, as discussed in the introduction, it is owing to the synergistic action of USTFs and NSTFs. STFs

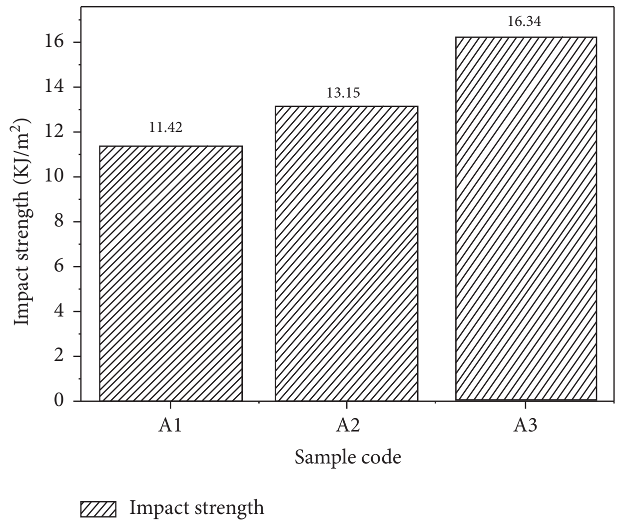
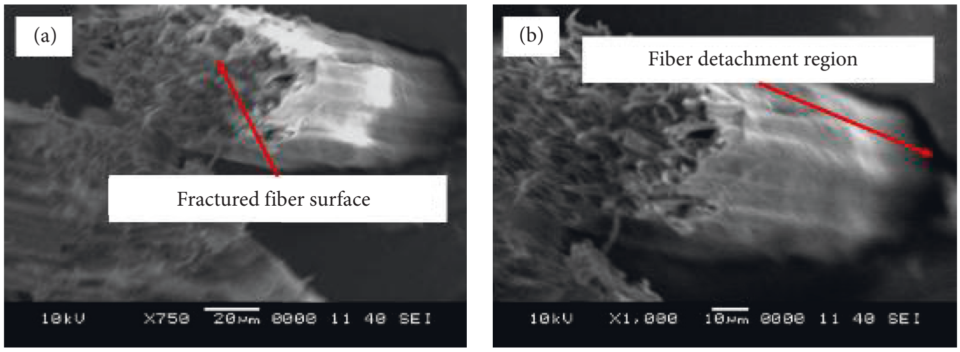


Figure 6: Impact strength results.

are having a hollow cellulose structure bonded with lignin and hemicelluloses. Cellulose and hemicelluloses are the primary parts of the plant cell walls, meanwhile, lignin fills the gaps between the cellulose fibrils, bonding both cellulose and other elements. The cell walls thicken as a result of the lignification process, and the carbohydrate is protected against chemical and physical harm. The natural cellulose structure was depolymerized by alkali treatment. Furthermore, during the NaOH treatment procedure, fibers are reversed and twined, as seen in mechanical characterization. Tensile strength may be reduced due to torsional stresses. Furthermore, NSTFs have a poorer dispersion in the polyester matrix than USTFs. USTFs may help to mitigate the problems of surface treatment, while also preserving the benefits of STF and improving the performance of polyester composites. Second, certain chemicals in the untreated STFs may have stimulated the development of a new crystal (beta) with higher mechanical characteristics. Lignin may aid in the nucleation and development of crystals [19]. Canetti discovered that the nucleating action of lignin formed a β-crystal of PP while keeping the original β-crystal. Third, fibers' lignin, wax, and other components may be advantageous for the inclusion of fibers and matrix. Because of its high dispersion, lignin is often utilized as a binder [20]. Rozman et al. [21] discovered that composites using lignin as a compatibilizer have better flexural characteristics than control composites [21]. According to previous investigations, hemicelluloses have also been shown to be effective in changing the cellulose microstructure due to their hydrophobicity. When hemicelluloses are removed, the comparatively flexible cellulose, hemicelluloses, cellulose link is replaced with the stiffer cellulose, cellulose bond, preventing stress redistribution and lowering strength qualities. As a result of combining NSTFs with USTFs, some valuable fiber components may be retained, improving composite interface qualities.

3.2. Thermogravimetric Analysis (TGA). Table 3 thermal properties of the developed polyester and STFs reinforced polyester composites. The weight percentage of polyester/USTFs and polyester composites began to rapidly decrease between 398°C which is mostly due to material deterioration. When the thermal degradation commenced, a second transition occurred between 360 and 380 degrees Celsius. From the TGA results, it was clear that the polyester with untreated fiber was more thermally stable. The fibers and polyester were exposed to heat and friction throughout the composites preparation process, resulting in thermal deterioration. As a consequence, the thermal stability of polyester/USTFs composites decreased when compared to plain polyester. Polyester/HSTFs also had greater thermal degradation temperature, indicating that polyester/HSTFs had superior thermal stability than polyester/NSTFs. In comparison to polyester/NSTFs composite, it can be determined that polyester/HSTFs composite has a more stable chemical structure. Another reason might be that the NaOH treatment has damaged the fiber structure. Another reason is that polyester/HSTFs have a greater crystallinity than other materials. Furthermore, the residual weight percentages of the three components differed from one another. The polyester/HSTFs composite contained the highest residues, while straight polyester had the least. Because of the SFs as reinforcement, polyester/SFs composites had a greater heat resistance than plain polyester, and HSTFs had a superior heat resistance than NSTFs.

3.3. SEM Analysis. Figure 7 shows the morphological analysis of developed samples. Fibers in the polyester matrix are randomly oriented, as shown in Figures 7(a) and 7(b). Polyester/HSTFs seemed to have a different microstructure. The SEM picture of polyester/HSTFs in Figure 7(a) was obtained at 750X zoom level. It was found that only fewer cavities indicating that more fibers were bonding together. Figure 7(b) shows tearing fibers, indicating that the strength of SFs was considerably reduced as a result of the NaOH treatment. The number of cavities in the SEM image of polyester/HSTFs (Figure 7(b) reduced, indicating that removing fibers from the matrix was more difficult and



(a) (b)

Figure 7: Morphology of polyester/HSTFs composite after tensile test.

Table 3: Thermal stability of the prepared samples.

Sample code	Initial degradation temp (°C)	Weight loss (%)	Final degradation temp (°C)	Weight loss (%)	Final residue (%)
Sample *A*1	398.52	31.14	—	—	58.01
Sample *A*2	268.16	34.82	355.14	24.74	30.15
Sample *A*3	282.24	37.59	388.24	23.68	28.34

interface strength was enhanced. This indicated that some chemicals in the USTFs had a good impact on interface strength. Figure 7(b) shows a crisp image of polyester/HSTFs magnified 1000×. The smooth fracture surface can be visible, which might indicate that certain USTFs were stronger than NSTFs and so served as reinforcement.

4. Conclusion

Using HSTFs as reinforcement instead of NSTFs might greatly enhance the mechanical and thermal characteristics of polyester composites. Polyester/HSTFs composite had 7.09%, 3.65%, and 24.2% greater in tensile strength, flexural strength, and impact strength compared to other compositions. Excellent matrix fiber interfacial bonding which might contribute to improved mechanical and thermal properties. The thermal residuals amount decreased in the hybrid composite and the decomposition temperature increased to 388.24°C in this composition due to hybridization and chemical treatment. Matrix fiber adhesion of polyester/HSTFs sample was better than that of polyester/NSTFs, according to SEM studies. Chemical treatment and hybridization increased the bonding strength due to the removal of wax and excessive oxides content in the outer surface of the fiber [22].

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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