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Comparative Study of Impact Strength Characteristics of Treated and Untreated Sisal Polyester Composites

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Abstract

In the present study both treated and untreated sisal polyester composites are tested to study its impact strength characteristics. ASTM D256 norms are followed to conduct the impact test on the specimens of 2 mm, 3 mm, 4 mm, 5 mm and 6 mm thicknesses for fiber volume of 10 %, 15 %, 20 %, 25 % and 30 %. Random orientation of fibers was adopted. Length of fibers used in casting the specimen is as 10 mm. Here all the specimens are fabricated by using manually operated hot compression moulding technique. The results obtained from the present study have shown that impact strength increases with increase in the thickness. Untreated sisal polyester composite yielded its peak impact strength of 3.581 N-m at its 30 % fiber volume fraction. Treated sisal polyester composite has shown highest impact strength of 1.962 N-m at its 30 % fiber volume fraction.

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Keywords: composite; sisal; impact strength; natural composite; treated sisal;

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1. Introduction

Since in some parts of the world, manufactured fibers like steel or glass fibers (fibers) are not easily accessible, attempts have been made to combine naturally available fibers isolated from plants in composite materials. A special aspect of these fibers is the easy processing for their extraction. A noteworthy issue in the usage of these fibers with matrix is that, they develop rough surface in the alkaline environment and subsequently durability of the composite

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includes concern. Since these fibers are efficient, attempts have been made to vanquish the issues of strength either by usage of fillers to reduce its alkalinity or by ensuring fibers by chemical treatment. Natural fibers used as a constituent of the composite are akwara, bamboo, coir, sisal, sugarcane bagasse and wood and elephant grass. Previously many researchers utilized the natural fibers as the option material for synthetic fibers in the manufacturing of composites. They also reported many results obtained from their study influencing the use of the materials. In the present study, an attempt has been made to study the impact strength of sisal fiber (diameter of 280 to 340 microns) reinforced polyester matrix composites. Botanical name of sisal plant is Agave sisalana, it is a species of Agave native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. It has sword-shaped leaves about 1.5–2 meters tall. The sisal plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibres. During the last thirty years, composite materials, plastics and ceramic production have polymers as main matrix materials. Regardless, in perspective of their higher specific strength, stiffness, fatigue resistance and adaptability in alkaline environment, composite materials have got recognised as very useful material.

Earlier researchers have reported studies on composites by using natural fibers as embedding material, among them Ghosh et al [1] have reported that banana fiber having high specific strength makes a light weight composite material and can be utilized to make light weight components of vehicles. Lu et al [2] have reported that the sisal/phenol formaldehyde composites made by the orchestrating (synthesizing) technique have demonstrated an increase of 17.61 %, 7.16 % and 12.25 % in impact strength, bending strength and bending modulus respectively when compared with routine physical blending strategy. Ali [3] has reported that coconut fibers are malleable and energy absorbent. Zaman et al [4] have demonstrated that mechanical properties of coir fiber reinforced composites have an intense relationship with their dynamic attributes. Sathiyamurthy et al [5] have reported that Artificial Neural Network (ANN) models can be utilized successfully to predict the mechanical properties of inorganic fillers impregnated coir - polyester composites. Gowda et al [6] have reported that the elasticity (tensile strength) of coir fiber reinforced polyester composite is generally high when compared with sisal fiber strengthened polyester composites; and that natural fiber strengthened composites can be viewed as a valuable light weight building material. Prasad et al [7] have reported that the feed forward ANN model could be a decent scientific tool for forecast of properties of coir fiber reinforced epoxy resin composites.

Further, Verma et al [8] have reported that some natural fiber composites have demonstrated mechanical properties similar to glass fiber composites and are being utilized as a part of furniture and other related commercial ventures. Karthik et al [9] have studied the surface roughness values of composites fabricated by utilizing boiled egg shell, rice husk particulate (15 %) and coir fiber (10 %). The study has shown that higher surface roughness values are recorded when fibers of 10 mm length are utilized when compared with the values obtained utilizing fibers of 30 mm length. Li et al [10] have reported in their study that natural fibers (fibers) can be a potential substitution for a synthetic fiber in composite materials. Kuriakose et al [11] have reported that grip (adhesion) at fiber - matrix interface can be enhanced by sodium hydroxide treatment – mercerization of the fibers. This treatment makes permeable surface prompting a rough surface texture which permits coir fibers to strengthen emphatically with polyester matrix. Idicula et al [12] have reported the mechanical performance of short randomly arranged banana and sisal inter crossed (hybrid) fiber strengthened polyester composites. With reference to the relative volume fraction of those two fibers, at a consistent aggregate fiber stacking of 0.40 volume fractions, keeping banana as the skin material and sisal as the centre material, the impact strength of the composites were increased with fiber stacking. The tensile and flexural properties of particular composite were observed to be better at 0.40 volume fraction. Girisha et al [13] have reported that natural fibers (sisal and coconut coir) strengthened epoxy composites were subjected to water soaking tests keeping in mind the end goal to study about the impacts of water absorption on mechanical properties. Natural fibers like coir (short fibers) and sisal fibers (long fibers) were utilized as a hybrid mix and the fiber weight portion of 20 %, 30 % and 40 % for the fabrication of the composite. Water absorption tests were accounted by soaking specimens in a water bath at 25o C and 100o C for various time durations. The tensile and flexural properties of water soaked specimens subjected to both aging conditions were assessed and compared with dry composite specimens. The rate of moisture uptake was found to increase with increase in fiber volume fraction, it is because of the high cellulose content of the fiber. The tensile and flexural properties of natural fiber reinforced epoxy composite specimens were found to decrease with increase in rate of dampness (moisture) uptake. Dampness prompted degradation of composite samples was seen at elevated (high) temperature.

Moreover, Sen et al [14] have portrayed that the materials considered for structural utilization must be functionally proficient and feasible. The utilization of composites in structural facilities is at present generally focused on enhancing the strength of the structure with the use of synthetic fibers and does not address the issue of sustainability of the raw materials utilized. Sisal is a huge source of natural fiber utilized for making ropes, mats, floor coverings and as reinforcement with cement. In developing nations, sisal fibers are utilized as roofing materials. Thomas et al [15] have studied the mechanical properties of cross breed ligno - cellulosic fiber strengthened natural rubber composites. The target of their study was to examine the effect of the proportions of sisal and oil palm fibers on tensile properties of natural rubber composites. The mechanical properties were observed to be more subject to sisal fiber than oil palm. The extent of fiber arrangement was observed to be progressive when sisal and oil palm was available in equal amounts. Bujang et al [16] have examined the effect of coir fibers volume on mechanical properties and dynamic characteristics of composite. They reported that the mechanical properties have a strong relationship with the dynamic characteristics. Both the properties are more dependent on the volume percentage of fibers. The tensile strength of composite was observed to be directly relative to the natural frequency. In addition, the damping ratio was observed to be increased by embedding of coir fibers which gives favourable environment to the structure in decreasing the high resonant amplitude. Riedel et al [17] reported that the fibers serve as a reinforcement and show high tensile strength and stiffness, while the matrix holds the fibers together, transmits the shear forces, furthermore works as a covering. Further criteria for the decision of appropriate strengthening fibers incorporate elongation at failure; thermal stability; adhesion of the fibers and matrix; dynamic behaviour; long-term behaviour; price and processing costs. Sabah et al [18] delineates that natural fiber when utilized as reinforcement replaces the man manufactured fibers like glass fiber. Till date, the most vital characteristic fibers utilized as a part of composites are Jute, flax, sisal and coir. Natural fibers are renewable raw materials and they are recyclable. Joshy et al [19] have reported in their article that untreated randomly arranged isora fiber reinforced polyester composite showed an initial decreasing in the tensile and flexural properties at 10% fiber loadings, found to have increased up to 34 % fiber stacking and after that declination with higher fiber stacking. 30 mm long randomly arranged isora fiber recorded as ideal length at which successful stress transfer amongst fiber and the matrix takes place. Authors reported that higher fiber lengths lead to fiber-fiber contact, fiber twisting results in shortening of viable fiber length beneath the critical value, yet short fiber length prompts notching effect results in significant stress concentration and generation of smaller scale cracks. In assessment of flexural properties, authors recorded flexural stress-strain behaviour at 40 mm fiber length. Authors reported increase in impact strength with increase in fiber stacking and recorded most noteworthy impact strength at 48 % fiber volume fraction whose further changes as for fiber volume fraction is not important. They also reported that in their present study that the mechanical properties of randomly oriented isora fiber reinforced polyester matrix composite displays less fiber matrix interaction at the initial level of fiber stacking. At its ideal level of fiber stacking indicated great fiber matrix interaction yet after that level authors observed poor scattering of fibers in the matrix resulted in decreasing of the mechanical properties. Chandramohan et al [20] have presented from their study that natural fibers reinforced composite can be adequately used to fabricate composite for the bone implant, car (automotive) parts, furniture, upholstery, family merchandise and PC products. Sumaila et al [21] have reported the influence of length of banana fibers on its mechanical properties. Author’s utilized 30 % weight randomly arranged nonwoven short banana fiber strengthened epoxy composite of 5 mm thickness for their study. With increase in the fiber length the density and impact strength of composites decreases. Tensile strength, tensile modulus and percent elongation of 15 mm long fiber reinforced composite material recorded the most noteworthy value. Here fibers were treated with 5 % NaOH solution before fabrication, and flexural strength and modulus of composite material increased with increase in fiber length up to 25 mm.

Sreekumar et al [22] reported the dynamic mechanical properties of sisal fiber strengthened polyester composites manufactured by resin transfer moulding. Examination demonstrated that at all the temperature range the storage modulus value is most extreme for the composite having fiber stacking of 40 % volume furthermore observed that the loss modulus and damping peaks were brought down with increasing fiber content. Silva et al [23] reported the potential utilization of long aligned sisal fibers as support in thin cement based laminates for semi-structural and structural applications. Naidu et al [24] reported that the tensile and flexural strength of sisal/glass fiber hybrid component is higher than sisal fiber reinforced composite, yet lower than the glass strengthened composite. Ma et al [25] have reported in their article that when there is enhancement in the twist level of fibers, the mechanical properties of those natural fiber-reinforced polymeric matrix composites decreasees. Authors utilized Sisal fibers yarns as reinforcing material with phenolic resin as matrix to manufacture the composite panels. Gowda et al [26] have reported in their study that ANN can be viably used to anticipate the tensile properties of untreated coir strengthened polyester matrix composites. Gowda et al [27] have reported in their article that probabilistic methodology could be viably used to forecast the range of tensile properties of coir reinforced polyester matrix composites. Prasad et al [28] have reported in their article that ANN is one of the better tools to anticipate the flexural properties of coir polyester composites.

From the literatures, it is observed that more detailed study is important in the area of investigation of impact properties of sisal fiber strengthened polymer matrix (both raw and 5 % NaOH treated) composites for various thicknesses and respective fiber volume fractions. Henceforth the present study intends to compute the impact strength of sisal fiber reinforced polyester matrix composite for various fiber loading's between 10 % to 30 % and distinctive thickness from 2 mm to 6 mm.

2. Materials and methods

In the present study untreated and 5 % NaOH treated sisal fiber is utilized as reinforcement, polyester resin as matrix, cobalt napthanate as curing agent and methyl ethyl ketone peroxide as catalyst. Polyester resins are unsaturated synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Maleic Anhydride is a commonly used raw material with diacid functionality. Unsaturated polyesters are condensation polymers formed by the reaction of polyols (also known as polyhydric alcohols), organic compounds with multiple alcohol or hydroxy functional groups, with saturated or unsaturated dibasic acids. Manufacture of specimens is performed by utilizing manual operated, temperature controlled compression moulding machine. The knotted fibers are obtained from sisal plants and are cleaned up. These fibers are passed through a Knot Separating Machine to evacuate the bunch and to separate individual fibers. The fibers acquired from bunch isolating machine are dried in daylight for a period of 48 hrs to remove the dampness. Fibers are cut to a length of 10 mm to be utilized as a part of randomly oriented fiber mats. In this stage, the spacers are utilized for casting composite boards of size 300 mm x 300 mm with varying thicknesses (2mm, 3 mm, 5 mm, and 6 mm).

These are placed on the base plate and a thick mylar (a non sticky) sheet is placed in between spacers and base plate for the easy removal of composite specimen after fabrication. Resin, catalyst and hardener are mixed in a proportion of 50:1:1 that is 1000 ml: 20 ml: 20 ml in ratio and stirred well. A 10 mm long sisal fiber of required fiber volume fraction (10 %, 15 %, 20 %, 25 % and 30 %) is weighed and distributed uniformly at the bottom of the mould inside the spacers. Compression load is then applied for 15 minutes on mould containing the fibers. Resin is then applied uniformly on fibers. Another releasing mylar sheet is spread over as the top surface with a steel plate and then the specimen is compressed for one hour for uniform distribution of matrix and elimination of entrapped air bubble if any. Here the temperature of both base plates are maintained for 60o Celsius. The composite is removed from the mould and left for curing at room temperature for 24 hours after which the desired composite specimens were cut from the casted composite panels. The Izod impact strength of every specimen in the present study is determined according to ASTM standard D-256 [29]. The sizes of testing specimens are considered as 65 mm x 13 mm x ‘t’, where ‘t’ is the thickness of specimens varied from 2 mm to 6 mm.

3. Results and discussions

Table 1 shows the impact strength of untreated sisal-polyester composites. Figure 1 shows the variation of impact strength of untreated sisal-polyester composites with fiber volume fractions. All the 2 mm, 3 mm, 4 mm, 5 mm and 6 mm thick specimens have shown their highest values as 1.079 N-m, 1.550 N-m, 1.937 N-m, 2.011 N-m and 3.581 N-m respectively at their 30 % fiber volume fractions. Table 2 shows the impact strength properties of treated sisal-polyester composites. Figure 2 shows the variation of impact strength of treated sisal-polyester composites with fiber volume fractions. Here 2 mm, 3 mm, 4 mm, 5 mm and 6 mm thick specimens have shown their highest impact strength of 0.932 N-m, 1,079 N-m, 1.128 N-m, 1.472 N-m and 1.962 N-m at their 30 % fiber volume fractions respectively. From Figure 2 it is observed that, as there is an increase of the thickness of the specimen, impact strength also increases. From tables 1 and 2 it is observed that, impact strength of all the untreated sisal-polyester composites recorded the most noteworthy values compared with respective treated sisal-polyester composites. So the above results demonstrates that, the NaOH concentration (5 %) adopted to carry out alkaline treatment for sisal fibers and the time duration of treatment process are inadequate to increase the impact strength of all treated sisal-polyester composites. Henceforth, there is a necessity to decide the ideal (optimum) NaOH concentration and the time duration for the treatment of natural fibers like sisal (refer [30], [31] and [32]).

Table 1: Impact strength properties of untreated sisal fiber reinforced polyester composites.

SI No	Thickness (mm)	Fiber Volume Fraction (%)	Impact strength (N-m)
1	2	10	0.319
2	2	15	0.809
3	2	20	0.888
4	2	25	0.956
5	2	30	1.079
6	3	10	0.510
7	3	15	0.863
8	3	20	1.324
9	3	25	1.472
10	3	30	1.550
11	4	10	0.687
12	4	15	0.981
13	4	20	1.373
14	4	25	1.913
15	4	30	1.937
16	5	10	0.883
17	5	15	1.216
18	5	20	1.619
19	5	25	1.962
20	5	30	2.011
21	6	10	0.893
22	6	15	2.207
23	6	20	2.796
24	6	25	3.384
25	6	30	3.581

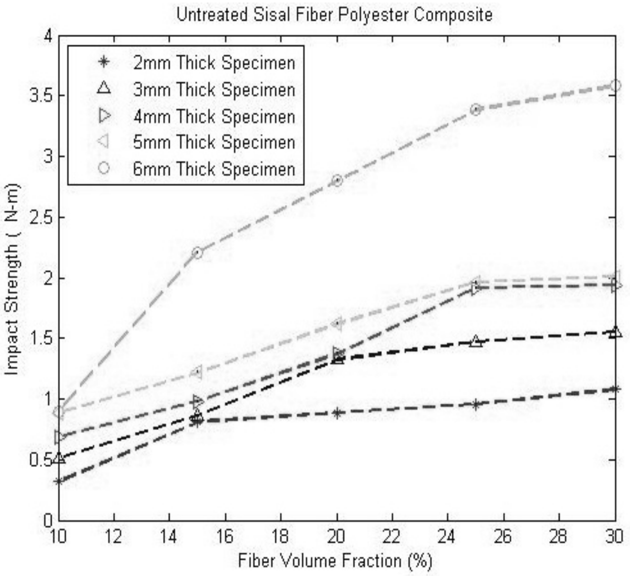

Figure 1: Variation of Impact strength of untreated sisal fiber reinforced polyester composites with fiber volume fraction.

Table 2: Impact strength properties of treated sisal fiber reinforced polyester composites.

SI No	Thickness (mm)	Fiber Volume Fraction (%)	Impact strength (N-m)
1	2	10	0.368
2	2	15	0.491
3	2	20	0.638
4	2	25	0.785
5	2	30	0.932
6	3	10	0.392
7	3	15	0.687
8	3	20	0.883
9	3	25	1.030
10	3	30	1.079
11	4	10	0.441
12	4	15	0.736
13	4	20	1.055
14	4	25	1.079
15	4	30	1.128
16	5	10	0.491
17	5	15	0.785
18	5	20	1.128
19	5	25	1.177
20	5	30	1.472
21	6	10	0.542
22	6	15	0.839
23	6	20	1.177
24	6	25	1.275
25	6	30	1.962

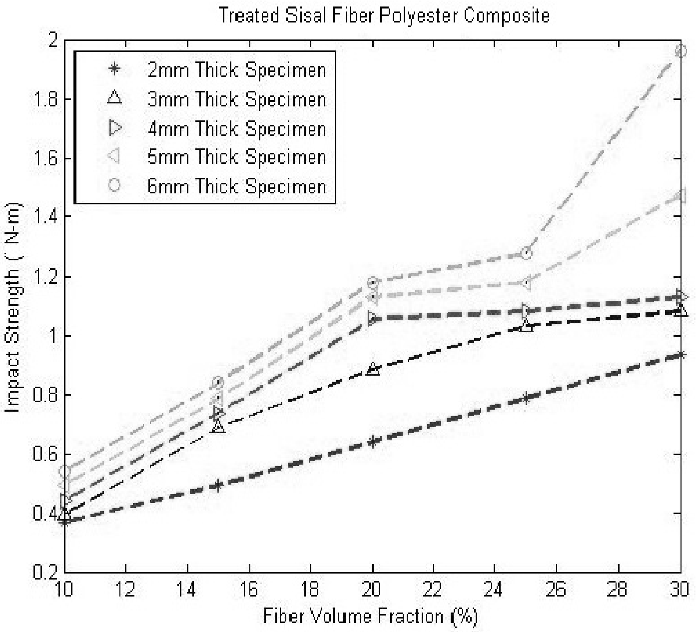

Figure 2 Variation of Impact strength of treated sisal fiber reinforced polyester composites with fiber volume fraction.

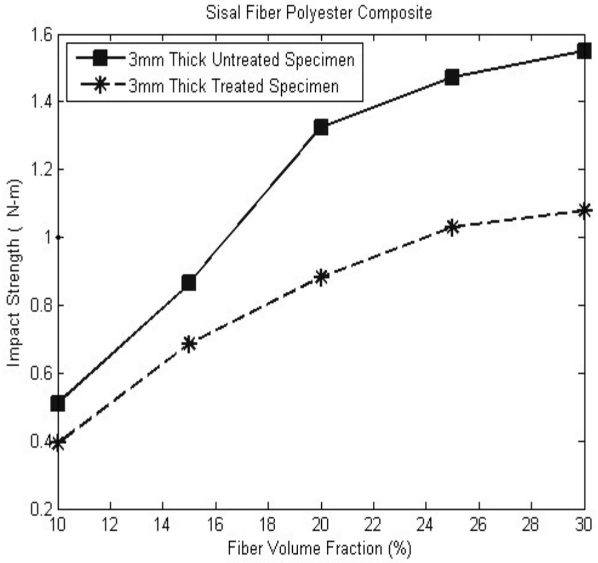

Figure 3: Illustration of variation of impact strength of 3 mm thick treated and untreated sisal fiber reinforced polyester composites with fiber volume fraction

4. Conclusions

Figures 1 and 2 show that impact strength of both untreated and 5 % NaOH treated sisal fiber embedded polyester matrix composites increases with increase in their thickness and fiber volume fraction. Comparing the impact strength values of tables 1 and 2 (refer Figure 3) it is concluded that, 5 % NaOH treatment to 10 mm long sisal fibers for 24 hours treatment period is insufficient to enhance the impact strength properties of sisal-polyester composites. Usage of this kind of plant fiber reinforced composites as Light doom, Mudguards, name and number plates and Engine guard in automobiles; switch gear, panels and insulators in electrical industries.

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