Physical Properties of Short Sisal Fiber Filled Polyester Composites

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Abstract- The present work aims at developing a new class of polymer composites with polyester as matrix material and short sisal fiber as filler material.Composites are prepared using hand lay-up technique.The effect of fiber content on physical properties of such fabricated samples are investigated and presented in this work. The various property evaluated are density, void content, and water absorption rateof the fabricated samples. From the experimental results, it is found that density of the composite decreasesand void content increases as a linear function of sisal fiber content. Water absorption rate increases with increase in fiber content and immersion time.

Keywords: Polymer matrix composites, Polyester, Sisal fiber, Density, Water absorption rate.

I.INTRODUCTION

In the last few decades, natural fiber-reinforced polymer composites have received substantial attention in the field of research and innovation [1, 2]. Natural fibers can be sourced from plants or animals. Among the two natural fibers obtained, plants fibers find more potential application in polymer composites. Natural fibers obtained from plants are harvested from renewable resources and readily available at low prices. Their specific properties are comparable to synthetic fibers (e.g., glass fibers) that are traditionally used as reinforcing phases in polymer based composite materials [3, 4]. The plant, which produces cellulose fibers can be classified into bast fibers (jute, flax, ramie, hemp and kenaf), seed fibers (cotton, coir and kapok), leaf fiber (sisal, pineapple and banana), grass and reed fibers (rice, corn and wheat) and core fibers (hemp, kenaf and jute) as well as all other kinds (wood and roots) [5].

Fiber reinforced polymer composites are in great use because of the good properties and superior advantages of natural fiber over synthetic fibers in terms of its relatively low weight, low cost, less damage to processing equipments, good relative mechanical properties, improved surface finish, renewable resources, being abundant, biodegrability and minimal health hazards [6]. Among the different types of natural fibers, sisal fibers are a promising reinforcement for use in composites.

Maurya et al. [7] worked on epoxy reinforced with short sisal fiber and evaluated the mechanical properties of the composites as a function of fiber length. They used four different length fiber ranging from 5 mm to 20 mm with an increment of 5 mm and kept the fiber loading constant to 30 wt. %. They fabricated the composites via hand lay-up method and evaluated the tensile strength and flexural strength of it. In their analysis, they found that the flexural strength increases with increase in the length of the fiber whereas tensile strength decreases with increase in length of fiber. Decreasing trend in tensile strength is due to improper wetting and adhesion between fiber and matrix. Gupta et al. [8] used epoxy matrix with sisal fiber and fabricated the composite by hand lay-up method. They studied the effect of fiber content and types on various mechanical properties of the composites. In their analysis, they found to achieve maximum tensile strength and flexural strength with maximum fiber content of 30 wt. %. Also, they concluded that fiber in mat form given better results as compared to unidirectional fibers. Zhou et al. [9] et al. used combination of short sisal fiber with high density polyethylene matrix and fabricated the composites using twin screw extruder. They fabricated two sets of composites with 10 wt. % and 20 wt. % fiber and found that the tensile and flexural strength increases for 10 wt. % fiber and decreases for 20 wt. %. Though, both sets show better properties than virgin HDPE polymer. For maximum fiber content, they reported to achieve only 25.5 MPa tensile strength over 24.8 MPa for pure HDPE. When, sisal fibers were incorporated in polypropylene polymer, Hasmi et al. [10] observed continuous increasing trends in all the mechanical properties under investigation. Also, they reported to achieve significant improvement in the mechanical properties. In their work, tensile strength increases from 31.26 MPa to 48.99 MPa and flexural strength increases from 48.03 MPa to 64.51 MPa when fiber weight fraction increases from 0 wt. % (pure PP) to 30 wt. %.

It has been seen that reinforcement of sisal fiber enhances the mechanical properties of the polymeric resin. Further improvement in properties can be achieved by using surface modified sisal fiber. Influence of concentration of chemical used and time of treatment on sisal fiber and its properties have been studied and reported by the various researchers. Sisal fiber were mainly treated with NaOH and silane to provide successful results but in recent research work various other chemical are also been explored over sisal fiber. The promising chemicals are peroxide, acetylation, potassium permanganate, baking soda and ultrasonication. Fiore et al. [11] modified the surface of sisal fiber with baking soda. This baking soda has chemical name as sodium bicarbonate. They treated the sisal fiber for different time period ranging from 0 hour to 240 hours. The time period chosen by them are 0, 24, 120 and 240 hours. They fabricated four different sets of composites and evaluated the flexural properties of the composites as a function of treatment time. In their study, they found that flexural strength and flexural modulus increases with treatment hour upto 120 hours and later decreases when treatment time increases to 240 hours. They explained the phenomenon as surface modification enhances the property of fiber and adhesion between fiber and matrix. As treatment time increases, adhesion properties also increase but once the treatment time increases beyond critical time, it starts to break the fiber internally and reduces the strength of the fiber results in overall decrement in the value to flexural

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properties.
Naushad et al. [12] also used the combination of PP and sisal fiber and they used NaOH with maleic anhydride grafted PP and found that the tensile and flexural properties increase. MAPP supported the increment in properties. When they evaluated the mechanical properties of the material by reinforcing 40 wt. % of untreated fiber in PP matrix, they not found noticeable increment in mechanical properties. The mechanical properties evaluated by them are tensile and flexural properties. When the surface of sisal fiber was treated, they found improved adhesion between the fiber and matrix phase. This improved adhesion results in improvement in tensile and flexural properties of the material. They further evaluated the damage tolerance of the material by performing cyclic tensile test. Damage tolerance is also reported to improve with treated fibers. Against this background, an attempt has been made in this research work to develop short sisal fiber (SSF) based polyester composites using simple hand lay-up technique and to study their physical properties i.e. density, void content and water absorption rate with varying fiber content.

II. MATERIAL CONSIDERED

Unsaturated isophthalic polyester supplied by Ciba-Geigy India Ltd. is taken as the matrix materials in the present investigation. Polyester is a category of polymer which contains the ester functional group in their main chain. The term unsaturated polyester resin is generally referred to the unsaturated (means containing chemical double bonds) resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resin is also known as a thermosetting plastic, which implies the plastic sets at high temperatures. Polyester resin composites are cost effective because they require minimal setup costs and the physical properties can be tailored to specific applications. Some important properties of polyester resin are given in table 1.

TABLE I IMPORTANT PROPERTIES OF POLYESTER RESIN

Property	Value	Unit
Density	1.09	gm/cm^3
Modulus of elasticity	3.3	GPa
Tensile strength	40	MPa
Compressive strength	82	MPa
Flexural strength	45	MPa
Maximum elongation	1	%

The sisal fiber used in present work was extracted from the leaf of the plant Agave-Sisalana which is available in plenty in the Southern part of India. It is an herbaceous monocotyledonous plant from the Agavaceae family that consists of a rosette of sword-shaped leaves about 100–150 cm tall and 13–15 cm wide. A sisal plant has a 7 to 10-year life-span and produces about 200–250 leaves. When the plant completed two year of its growth, the fiber can be extracted from sisal leaf. By this this they reach a length of 80-100 cm. Among the various natural fibers, sisal fiber is chosen in present work because it is easily and cheaply available. Also, it possesses reasonably good physical and mechanical properties. The various physical and mechanical properties of sisal fiber used in present investigation are presented in Table 2.

III.SAMPLE PREPARATION

In the present investigation, short fiber reinforced polyester composite is fabricated using simple hand lay-up technique. The fabrication of composite using hand lay-up method involves following steps:

TABLE II IMPORTANT PROPERTIES OF SISAL FIBER

Characteristic Property	Values	Units
Density	1.41	g/cm^3
Elongation at break	2-2.5	%
Tensile strength	511-700	MPa
Young ‘s modulus	9.4-22	GPa
Water absorption	11	%

The room temperature curing polyester and corresponding hardener methyl ethyl ketone peroxide (MEKP) are mixed in which hardener is added 2 % by weight as recommended.

1. Sisal fiber in its short form with approximate size of 3 mm will then added to the polyester-hardener combination and mixed thoroughly by hand stirring.
2. Before pouring the polyester/fiber mixture in the mould, a silicon spray is done over the mould so that it will be easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould so as to get the specimens as per ASTM standard for the entire characterization test.
3. The cast is than cured for 8 hours before it was removed from the mould. In this process exothermic reaction between the matrix and hardener occur which hardened the composite body in this specified duration.

Composites were fabricated with different weight fraction of filler ranging from 0 to 15 wt. %. The list of fabricated composites in present work is presented in table 3.

TABLE I. LIST OF POLYESTER COMPOSITES REINFORCED WITH SHORT SISAL FIBER.

S.No.	Set	Composition
1	Set 1	Neat Polyester
2	Set 2	Polyester + 3 % by weight sisal fiber
3	Set 3	Polyester + 6 % by weight sisal fiber
4	Set 4	Polyester + 9 % by weight sisal fiber
5	Set 5	Polyester + 12 % by weight sisal fiber
6	Set 6	Polyester + 15 % by weight sisal fiber

IV.EXPERIMENTAL DETAILS

The experimental density (ρ_{ce}) of composites under study is determined by using Archimedes principle using distilled water as a medium (ASTM D 792-91). The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents can easily be obtained using rule of mixture model. Comparison of experimental and theoretical density gives voids generated during fabrication of composites. Water absorption test were carried out to analyze the behaviour of composite in the presence of water affected environments. Mainly the test was conducted in normal water to assess the amount of water absorbed by the composite according to ASTM D 570-98 standard.

V.RESULTS AND DISCUSSION

A. Densityand void content

All the three values, i.e. theoretical values, measured values, and the corresponding void content were presented in table 4. From the table it is observed that density of the composite decreases when sisal fiber was added in polyester matrix. From the table it can be observed that for maximum content of filler, the density of the composite reduces to 1.03 g/cm^3 when sisal fiber of 15 wt. % were used as reinforcement. This is a decrement of 7.73 % in density as compared to neat polyester.

TABLE 4 VARIATION OF THEORETICAL AND MEASURED DENSITY WITH DIFFERENT FIBER CONTENT

Set No.	Theoretical density (g/cm^3)	Measured density (g/cm^3)	Void content (%)
Set 1	-	1.09	-
Set 2	1.097	1.08	1.57
Set 3	1.104	1.07	3.13
Set 4	1.112	1.05	5.58
Set 5	1.119	1.03	8.01
Set 6	1.127	1.01	10.41

It is noted from the tables that the calculated values of density using rule of mixture model are higher as compared to the values obtained from experimentation. The main reason behind this is when we are calculating the density theoretically; we are taking into account about the number of voids generated, as theoretical formula not considered its content, whereas we have seen that fabrication of composite will always give rise to certain voids. We know that density of voids will always be less than the density of composites. While doing experimentation the effects of voids were also come into play and we get reduced density of composite than theoretical. Also, it is observed that void content slightly increases with filler content. The maximum void content is of 10.41 % when 15 wt. % of sisal fiber is used in polyester matrix.

B. Water Absorption Behavior

Figure 1 shows the deviation in water absorption rate of fabricated sets of specimens as a function of fiber content for different immersion time. Maximum water absorption for neat polyester is 1.5 %. It can be observed from the figure that water absorption rate increases as a function of fiber content.

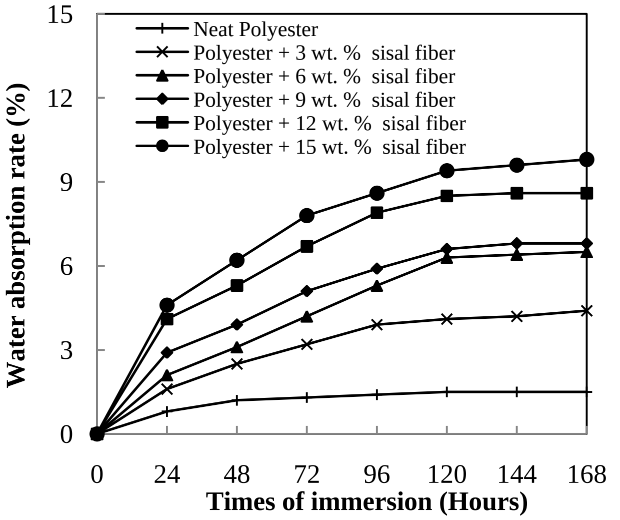

Fig. 1 Water absorption rates of polyester/sisal fiber composites as a function of fiber content and immersion time

The phenomenon can be explained by considering the hydrophilic nature of sisal fiber which is responsible of water uptake characteristics as the neat polyester has negligible water absorption. Apart from fiber content, immersion time greatly govern the percentage of water absorption. Water absorption rate increases with increase in immersion time. Further, water absorption rate is maximum for initial hours of immersion which gradually decreases with time and after certain interval of time, a saturation curve is obtained i.e. no further intake of water is registered.

VI. CONCLUSIONS

This experimental investigation on short sisal fiber reinforced polyester composites has led to the following specific conclusions:

1. The density of the fabricated composites decreases with increase in weight fraction of the fiber content. The reduction in density is mainly because of low density of fiber.
2. With increase in fiber content, void content of the composite also increases. The maximum void content is 10.41 % maximum fiber content of 15 wt. %.
3. The water absorption rate increases with increase in fiber content and duration of immersion of composite body inside the water. With sisal fiber as reinforcement in polyester resin, maximum absorption rate is 9.8 % with 15 wt % fiber and for duration of 168 hours.

REFERENCE

[1] Saheb, D. N., & Jog, J. P. (1999). Natural fiber polymer composites: a review. Advances in Polymer Technology: Journal of the Polymer Processing Institute, 18(4), 351-363.

[2] Mohammed, L., Ansari, M. N., Pua, G., Jawaid, M., & Islam, M. S. (2015). A review on natural fiber reinforced polymer composite and its applications. International Journal of Polymer Science, 2015.

[3] Bledzki, A. K., &Gassan, J. (1999). Composites reinforced with cellulose based fibres. Progress in polymer science, 24(2), 221-274.

[4] Paul, W., Jan, I., &Ignaas, V. (2003). Natural fibers: can they replace glass in fiber reinforced plastics. Composites Science and Technology, 63, 1259-1264.

[5] Faruk, O., Bledzki, A. K., Fink, H. P., &Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. Progress in polymer science, 37(11), 1552-1596.

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[6] Shalwan, A., & Yousif, B. F. (2013). In state of art: mechanical and tribological behaviour of polymeric composites based on natural fibres. Materials & Design, 48, 14-24.

[7] H.O. Maurya, M. Gupta, R. Srivastava, H. Singh, Study on the mechanical properties of epoxy composite using short sisal fibre, Mater. Today: Proc. 2 (2015) 1347–1355.

[8] Gupta, M. K., & Srivastava, R. K. (2014). Tensile and flexural properties of sisal fibre reinforced epoxy composite: A comparison between unidirectional and mat form of fibres. Procedia materials science, 5, 2434-2439.

[9] Zhao, X., Li, R. K., & Bai, S. L. (2014). Mechanical properties of sisal fiber reinforced high density polyethylene composites: Effect of fiber content, interfacial compatibilization, and manufacturing process. Composites Part A: Applied Science and Manufacturing, 65, 169-174.

[10] Hashmi, S. A. R., Rajput, R. S., Naik, A., Chand, N., & Singh, R. K. (2015). Investigations on weld joining of sisal CSM-thermoplastic composites. Polymer Composites, 36(2), 214-220.

[11] Fiore, V., Scalici, T., Nicoletti, F., Vitale, G., Prestipino, M., &Valenza, A. (2016). A new eco-friendly chemical treatment of natural fibres: Effect of sodium bicarbonate on properties of sisal fibre and its epoxy composites. Composites Part B: Engineering, 85, 150-160.

[12] Naushad, M., Nayak, S. K., Mohanty, S., & Panda, B. P. (2017). Mechanical and damage tolerance behavior of short sisal fiber reinforced recycled polypropylene biocomposites. Journal of Composite, Materials, 51(8),1087-1097

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