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Sisal Fiber Reinforced Polypropylene Bio-Composites for Inherent Applications

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Abstract*: In recent times, there is considerable interest in the elaboration and use of bio-composites. Agricultural residues are preferred as reinforcements in these composites due to their abundant availability and need to find alternatives to the burning or burying of the residues which are one of the major causes of pollution. Sisal fiber is a widely available natural fiber which possesses excellent moisture and heat resistant properties. Attempts have been made earlier to study the properties of it reinforced with various reinforcements separately and as a hybrid with other fibers. In this study, it is been reinforced with polypropylene and the tensile, flexural and morphological properties have been analyzed. Furthermore, the flame resistance of the prepared composite was also determined. Tensile strength ranging from 22-52 MPa and flexural strength in the range of 57-120 MPa was obtained. The Young's modulus varied between 1651-5420 MPa whereas the flexural modulus lied in 3064-5462 MPa range. The composites possessed a Rockwell Hardness Number of 58-92 depending on the ratios of reinforcement. Compression molding technique made the work simple and cost-effective to fabricate composites with good mechanical properties. Using the residues in their native form provides an opportunity to add substantial value addition and decrease waste. Simultaneously, a possible substitute for non-biodegradable products can be developed.

Keywords: Bio-Composites, Sisal, Fiber Reinforced, Polypropylene (PP), Compression mold.

I. INTRODUCTION

Marriage of two or more materials is composites, additionally called composite materials. The expression composite material alludes to fiber reinforced plastics since this is the most normal and significant composites classification. In fiber-fortified plastic composites, the plastic is strengthened with fibers in like manner for various applications. The material, wherein the fibers are inserted is known as the matrix, while the fibers are known as the reinforcement [1]. Indeed, even steel fortified cement could be alluded to as a composite, in spite of the fact that it is once in a while thought about to be a piece of the composites family.

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Alongside the fiber-reinforced plastics, there are a wide assortment of composites like ceramic matrices with metal or ceramic fibers, metal matrix with metal fibres, and so on.

In this work, an investigation on the mechanical properties of sisal fiber reinforced with PP composite materials is finished. Sisal strands are stiff fibers normally utilized in making rope, twine and furthermore dartboards. Sisal plants are circumscribed with a rosette of sword-formed leaves about 1.5 to 2 meters tall. Delicate leaves may have a couple of littler teeth along their edges, however lose them as they develop. The strands are just about 4% of the plant by weight. Sisal is viewed as a plant of the tropics and subtropics since generation profits by temperatures over 25 o C. Fiber are extricated out by a procedure called decortications, where the leaves are squashed and later beaten by a turning wheel set with blunt blades. After this procedure, just the fibres remain while the wastewater flushes away different pieces of the leaf. Proper drying is basic as fiber quality depends prevalently on the moisture content [2]. This fibres are impervious to moisture and heat and have good tensile strength[3].

Yan Li et.al reviewed sisal as a good reinforcement for composites owing to its various advantages like high specific strength & modulus and easy availability. Various characteristics of sisal reinforced composites were reviewed in the work [4]. Similar work carried out by Ku Het. aland stated that the natural fiber reinforced polymers tensile properties (both thermoplastics and thermosets) were largely impacted by the interfacial adhesion between the reinforcements. and matrix

The fibers were exposed to various chemical modifications to improve the interfacial bonding which was seen to improvise the properties of the composite materials [5].

In another study, Paul Wambuaet.al compared the mechanical characteristics of various natural fiber reinforced PP composites. The tensile properties were directly dependent on the fiber volume fraction. Among all the fiber reinforced composites tested, hemp composites gave better results. Coir was found to have fared relatively bad with low mechanical properties [6].

Various studies have been carried out in this discipline of fiber reinforced composite materials but the scope of improvement is huge. In this work, efforts are made to study the characteristics of the sisal fibers reinforced with PP. Tensile and flexural properties as per ASTM standards along with the morphology of the composites are reported. The flammability and water

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absorption test were also being conducted.

II. MATERIALS AND METHODS

A. Materials

The sisal fiber was procured from Tamilnadu Agricultural University, Coimbatore, India. The PP used as the binder in this work was purchased from Indian Oil, Bangalore, India. The sisal fibers were pre-treated with 4% NaOH solution for 24 hours and washed several times after to bring it down to neutral pH and were dried naturally under Sun.

B. Fabrication of composites

Hand layup method was adopted to prepare the composite samples. Different ratios of sisal and binder PP were used to develop the composites using hot compression molding technique. The mold plates were cleaned thoroughly using acetone solution and aluminum foils were spread over to facilitate the facile removal of the specimen. Pre-preg was prepared by taking weighed amount of fibers and PP, layer of the matrix and reinforcement were randomly placed (orientation) between each other to create a sand-wich type structure. Later on the pre-preg was introduced to the mold and compressed for about 90seconds at 2000 psi to take shape of the flat mold. The mold was then cooled by passing water, opened and the samples were carefully removed and stored for further testing.

C. Tensile Test

Tensile characteristics (both strength and modulus) of the composite materials arranged were tried on a Universal Tensile Tester with a 1000 kg load cell prepared. As per ASTM standard, D 638-14 test tests (dog bone shaped) were removed with measurements of 165 mm length and 19 mm wide at widest section. Crosshead speed for tensile tests was 50 mm/min. Around 20 tests were tried and the average and standard deviation are accounted for..

D. Flexural Test

Flexural qualitieS, modulus and strength was also found by ASTM standard D790-15. Tests with a length of 203 mm and width of 76 mm were ready to deal with the flexural studies. Crosshead speed for flexural tests was 10 mm/min. 15 tests were tried for flexural properties for every proportion. The average and stand

E. Hardness Test

Rockwell hardness test was conducted on the specimens as per ASTM D785-98 standards of testing composite materials. It applies a minor load of 10kgf and major load of 60kgf (589N). A steel ball indenter of 6.35mm diameter was used and the red dial was observed for determining the Rockwell hardness number. The hardness was determined at 5 different points and the mean and standard deviation were noted down.

F. Water Absorption Test

Water absorption test was conducted with samples of size 80×50 mm, they were placed in a hot air oven at 104^0C for 2-3 hour to remove moisture, the initial weight (W_i) of the test samples was noted and then dipped in the water and final weight (W_f) of each sample for specific time intervals was noted down. Water absorption is calculated by the formula:

$$W.A\ (\%) = ((W_f-W_i)/W_i) \times 100$$

G. Flame Resistance Test

Samples of 125 mm x 13mm dimensions were cut-out from the prepared board and the flame resistance of the composite was determined according to the UL-94 standard test method. During the test, the samples were placed vertically above a Bunsen burner. The burner was brought in contact with the specimen for about ten seconds. The time taken for the flame to extinguish over time was recorded. Further, any dripping of the specimen onto the cotton fibers below the sample was also observed. Five samples were tested for each ratio and the flammability ratings were assigned based on the time to self-extinguish the flame by respective composite materials.

H. Morphological Analysis

A scanning electron microscope was deployed to observe the morphology of the composite materials. The distribution of the PP and sisal across the composite and the surface morphology were observed. Specimens were initially coated with gold-palladium and observed at a voltage of 4 kV.

III. RESULTS AND DISCUSSIONS

A. Mechanical Properties

The mechanical characteristics of the composites are shown in **Figures 1 to 3**.As can be seen from the graphs, the ratio of fiber to PP has a direct impact on the mechanical characteristics (both Tensile and Flexural) of the composite materials. As the fiber content was increased from 50% to 60% and then to 70%, a rise of 71% in Young's modulus from 3156 MPa to 5462 MPa was seen. On further increase in fiber content to 80%, the value dropped to 1651 MPa. As far as the flexural properties are concerned, the trend remained similar. The values of both modulus and strength were maximum for 70/30 ratio at 5420MPa and 52.42 MPa, for tensile and 5462 MPa and 120 MPa for flexural respectively, which shows that it is the best ratio in the lot. The hardness test results showed a similar trend too. The inferior mechanical properties of the 80/20 ratio could be attributed to the insufficient binder for bonding which leads to the fracture easily [7].

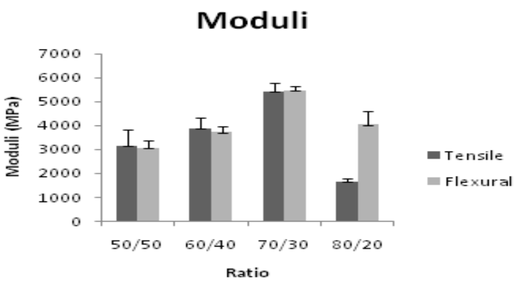

Figure 1 Variation of Tensile and Flexural Moduli of the composites at different ratios

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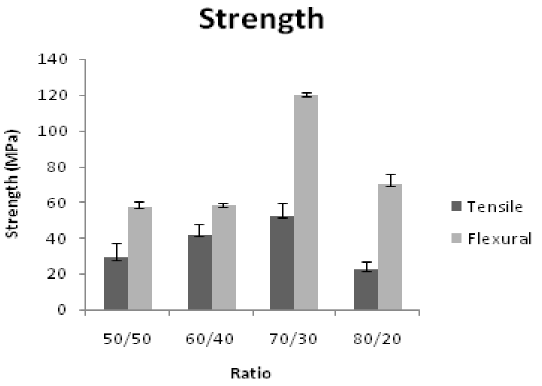

Figure 2 Variation of Tensile and Flexural Strength of the composites at different ratios

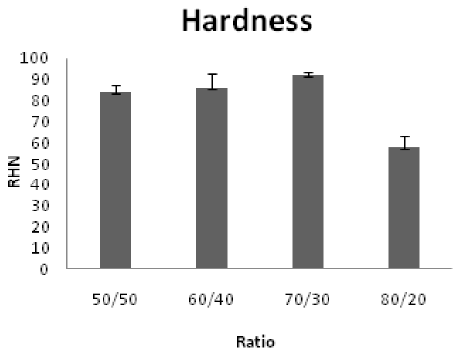

Figure 3 Variation of Hardness of the composites at different ratios

The surface morphology of sisal and PP composite is shown in **Figure 4**.A good adhesion between the sisal fiber and the binder could be seen and it is one of the main reasons in obtaining its superior mechanical properties. The interfacial bonding of the composite material can be seen in **Figure 5**. Owing to its high mechanical properties, the 70/30 ratio was chosen for the imaging. The bonding could be attributed to the NaOH wash as it largely removes the lignin wax and oils that cover the outer surfaces of the fiber walls [8]. Nevertheless, the presence of voids couldn't be avoided completely.

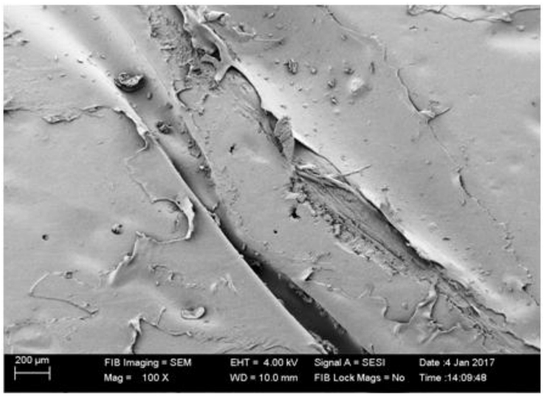

Figure 4 SEM image of the composite showing the surface morphology of the composite

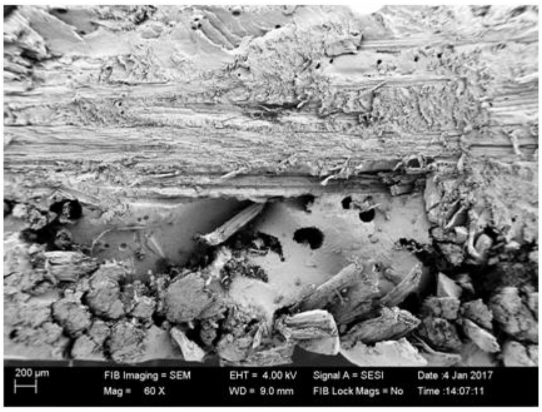

Figure 5 SEM image of the composite showing the packing of the fiber and PP

B. Water Absorption

The test results confirm that as the binder percentage increased, the water absorbed by the composite decreased which can be seen in **Figure 6**, also it was observed that the thickness of the composites varied between 0.84-1.13mm to the initial over a specified time.

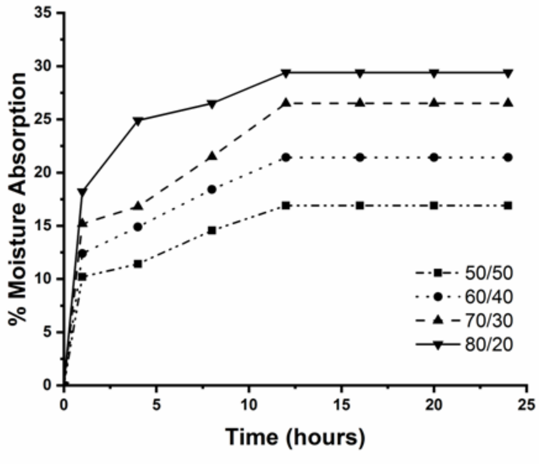

Figure 6 Water absorption test of the composites

C. Flame Resistance

Figure 7 Flame resistance test of the composites

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The flame resistance data is shown in **Table I**. From the table, it is seen that the varied ratio of fiber: PP had no effect on the flame resistance and passed the UL-94 V-1 rating [9]. The fire propagated through the composite but extinguished by itself (**Figure 7**). Also, there was no dripping observed which prevents further damage in case of any real-world fire scenario.

Table I Comparison of the flame resistance of the composite made using different proportions of sisal and PP

The proportion of fiber and PP	Time to self-extinguish after ignition(s)	Observed Dripping	UL-94 Rating
50:50	>250	No	V-1
60:40	>250	No	V-1
70:30	>250	No	V-1
80:20	>250	No	V-1

IV. CONCLUSION

A study on the mechanical characteristics of sisal reinforced composites with varying ratios of sisal fibers is attempted. From the experimental results, it can be seen that the ratio of sisal and PP influenced the mechanical characteristics of the composites. As the fiber: PP ratio raised, the strength and moduli values also increased till a certain limit. Acceptable changes were noticed in the water absorption test with minimal swelling. But in the method followed, voids in the composites couldn't be completely avoided. Composites in this research showed good properties which open a new door of applications like bio-electronics such as green printed circuit boards, aircraft luggage bins, false ceiling.

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