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GRADUATE RESEARCH ARTICLE

Investigation of Mechanical Properties of Sisal Fiber Reinforced Polymer Composites

Manjunath G. Prasad[1]. A. G. Girimath[1], Sharath Rao[1], A. J. Vinekar[1], D. C Patil[1], S. N. Timmanagoudar[1], S. N. Mathad*[2]

[1] Department of Mechanical Engineering, K.L.E. Institute of Technology, Hubballi-30
[2] Department of Physics, K.L.E. Institute of Technology, Hubballi-30

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*Corresponding Author email: physicssiddu@gmail.com

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Student(s)
- A. G. Girimath
- Sharath Rao
- A. J. Vinekar
- D. C Patil

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Mentor(s)
- Manjunath G. Prasad
- S. N. Timmanagoudar
- S. N. Mathad

ABSTRACT

The aim of this work is to study the influence of sisal fiber content on mechanical (i.e. tensile, flexural, impact, hardness and abrasion resistance) and thermal (i.e. TGA) properties of composites by varying the fiber and epoxy percentage. The composite was prepared by melt-mixing method, followed by compression molding process. The percentage of sisal fiber is varied from 4% to 10% in steps of 2%. Similarly epoxy content is varied from 96% to 90% in steps of 2%. Detailed mechanical Properties of Sisal Fiber Reinforced Polymer Composites have been studied. The major mechanical properties viz Tensile, Hardness, Impact, Flexural, Moisture absorption, and Moisture content are studied.

Keywords: Mechanical Properties; Sisal Fiber; Polymer Composites

1. Introduction

Composites have been widely used as cutting tools and wear resistance coating, because of its high hardness, good strength and toughness, chemical stability and excellent wear resistance [1]–[4]. High mechanical strength and excellent electrical conductivity of copper matrix composites, along with other properties, ensure a wide application range for these materials [2], [3]. Alumina silicate refractories are used in metallurgical, ceramic and glass industries [4]. Natural fibers are a major renewable resource material throughout the world specifically in the tropics. According to the food and agricultural organization survey, natural fibers like jute, sisal, coir, banana, etc. are abundantly available in developing countries [5], [6]. The

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use of natural plant fibers as a reinforcement in fiber-reinforced plastics (FRP) to replace synthetic fibers such as glass is receiving attention, because of advantages such as renewability, low density, and high specific strength. Recent studies have investigated the development of biodegradable composite materials using natural fibers such as flax [7], bamboo [8], pineapple [9], [10], oil palm empty fruit bunch [11]–[13] silk [14], sisal [15], jute [16], kenaf [17], rice husk [18] and ramie [19] as a reinforcement for biodegradable plastics. These studies have examined molding conditions, mechanical properties, and interfacial bonding. Natural fibers have gained a considerable attention due to benefits such as less abrasiveness to equipment, renewability, biodegradability, less health hazards and reduction in weight and cost. In composite materials, critical fiber loading is required to make effectiveness in load transfer between fibers and matrix. However, the processes involved in using natural plant fibers as reinforcement are different from those using industrial products such as glass and carbon fibers. The shape, size, and strength of the natural plant fibers may vary widely depending on cultivation environment, region of origin, and other characteristics. In turn, these features of the natural fibers are likely to influence the mechanical properties of the natural fiber-reinforced plastics [20].

M. Ramesh *et al.* [21] investigated the mechanical properties of sisal, jute and glass fiber reinforced polyester composites and observed that the addition of glass fiber into jute fiber composite resulted in maximum tensile strength. In the same way, they have observed that jute and sisal mixture composites sample is capable having maximum flexural strength and maximum impact strength was obtained for the sisal fiber composite. The variation of tensile strength, flexural strength and compressive strength of epoxy based sisal-glass hybrid composites has been studied by H. Ranganna *et al* and Goswami *el al* [22], [23] developed sisal natural fiber composites with and without silica by incorporating 100% biodegradable sisal fibers as reinforcement in the polyester matrix. The results showed that the tensile strength and tensile modulus of composites with silica are 1.5 and 1.08 times greater than that of composite without silica respectively. The impact strength of composite with sand 1.36 and 1.8 times greater than that of composites without silica and plain polyester, respectively. Kuruvilla Joseph *et al* [24] have surveyed the research work published in the field of sisal fiber reinforced polymer composite.

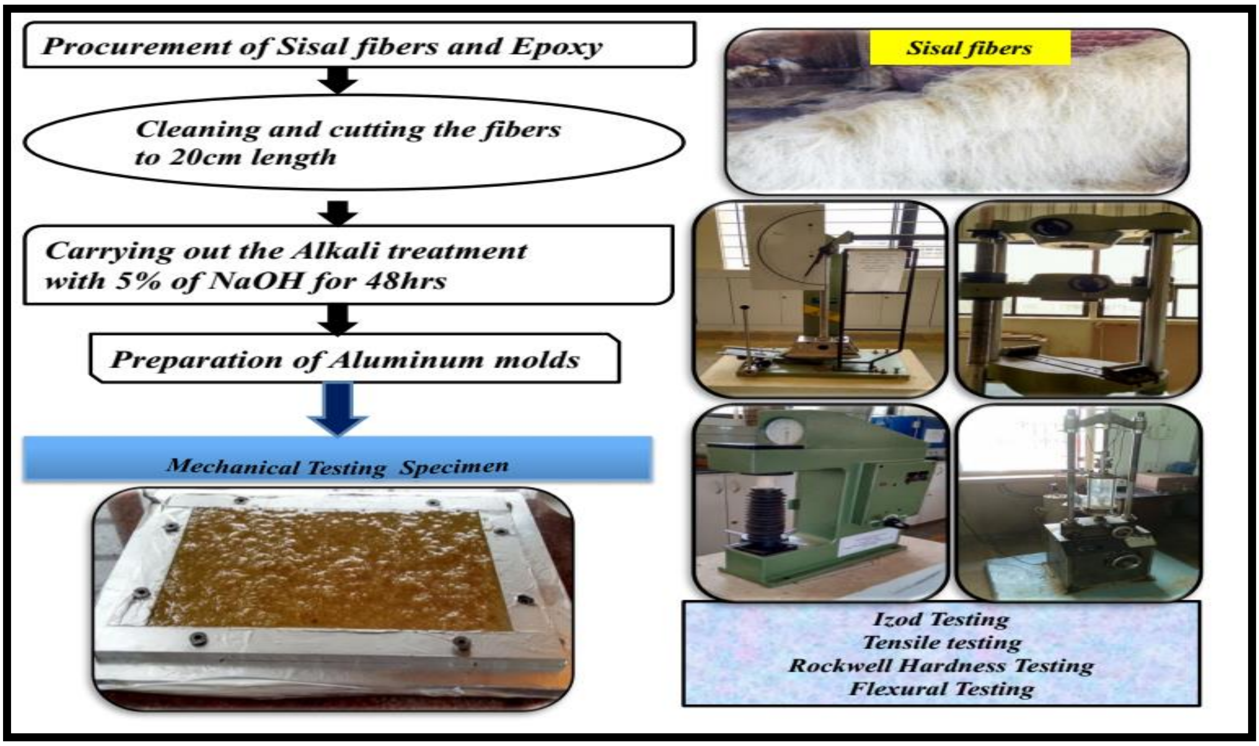

Figure 1: Schematic flow-chart of work

In this paper authors have highlighted the tensile strength of sisal, coir and banana fiber and it is found that sisal fiber has better tensile strength compared to other two fibers. Sisal fibers have good potential as reinforcements in polymer (thermoplastics, thermo sets and rubbers) composites. The aim of the study is to fabricate new class of epoxy based composites reinforced with randomly oriented short sisal fibers as shown in schematic flow-chart of Figure 1. The mechanical properties like tensile strength, flexural strength, impact and hardness of composites. Study the vibration characteristics like natural frequency and damping coefficient for these composites. Sketch the influence of fiber parameters such as fiber loading on the mechanical behavior and vibration characteristics of the composites. Analyze the moisture absorption and moisture content of the composite.

2. Material preparation

The fibers required for the testing were obtained from a small-scale rope making industry in Tayakanahalli, a village in Chitradurga district. The raw Sisal fiber is available in the form as shown in Figure 2.

Figure 2: *Raw form of Sisal fiber*

Figure 3: *Moulds and sample preparation for mechanical testing*

The long length fibers were first cleaned to remove the dust and other particles so as to use the fibers for further treatments. The fibers were cut to a length of 200 mm to make the further treatments easy. Alkali treatment is done using 5% NaOH in order to enhance the adhesion property of the fiber with epoxy resin. First the fibers are soaked in NaOH solution for 48hrs and then the fibers are washed in distilled water to remove the traces of NaOH. This treatment improves adhesion by removing the lignin and cellulose content. Aluminium moulds having dimensions of 230x160x7 for Mechanical properties testing as per the constraint of ASTM standards for thickness were first manufactured for composite fabrication and shown in Figure 3. The short sisal fibers are mixed with epoxy resin by simple mechanical stirring and the mixture was poured into various moulds, keeping in view the requirements of various testing conditions and characterization standards. The entrapped air bubbles (if any) are removed carefully with a sliding roller and the mould is closed for curing at a temperature of 30°C for 24 hours. After curing, the specimens of cut as per dimensions suggested by ASTM standards. In order to study the influence of sisal fiber, composites were prepared for different composition by varying the fiber and epoxy percentage. The percentage of sisal fiber is varied from 4% to 10% in steps of 2%. Similarly epoxy content is varied from 96% to 90% in steps of 2%. Different compositions are named as S1 to S4 as shown in the table 1. In this process hardener composition is kept constant.

Table 1: *Specimens based on different fiber loading*

Composite Type	Composition
S1	Epoxy (90 wt%), Sisal fiber(10 wt%) and Hardener (10 wt% of Epoxy).
S2	Epoxy (92 wt%), Sisal fiber(8 wt%) and Hardener (10 wt% of Epoxy).
S3	Epoxy (94 wt%), Sisal fiber(6 wt%) and Hardener (10 wt% of Epoxy).
S4	Epoxy (96 wt%), Sisal fiber(4 wt%) and Hardener (10 wt% of Epoxy).

3. Result and Discussions

3.1 Tensile test

According to ASTM D3039 / D3039M standards for composites, the specimens were prepared for tensile test. Fiber configuration and volume fraction are two important factors that affect the properties of the composite. The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The tensile testing machine and Specimen after failure are shown in Figures 4.

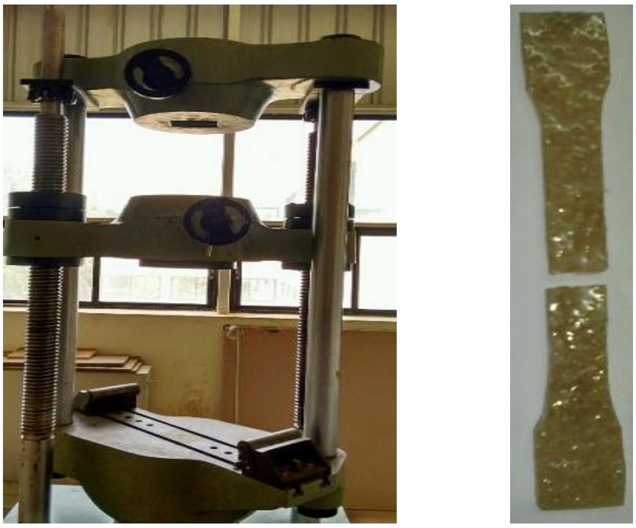

Figure 4: *Tensile testing machine and Specimen After failure*

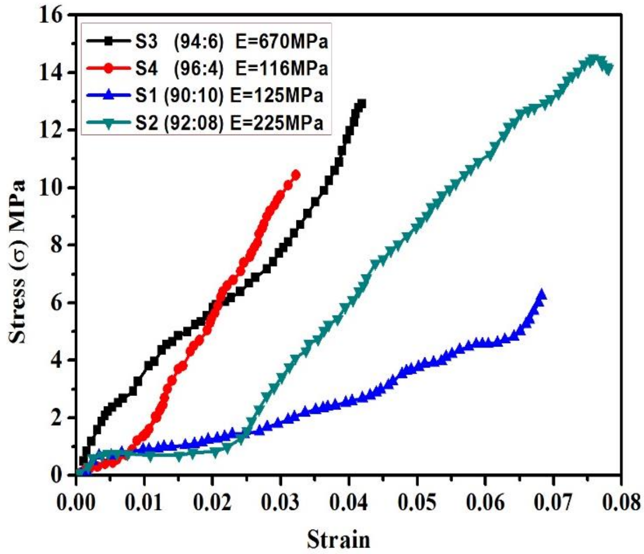

Figure 5: *Variation of stress vs strain*

Various prepared samples viz S1, S2, S3 and S4 are subjected to tensile loading. The values of load and displacement for corresponding fiber loadings were obtained from the post processor of UTM machine. The values of load were divided by area in order to get the stress values. Similarly, to get the corresponding strain values, displacement is divided by the gauge length. A graph of stress vs strain is plotted as shown in the Figure 5. From the figure, it is clear that nature of stress and strain is not same for different samples.

The ductility is observed to be more in case of S2 and S1 samples. Young's modulus is more for S3 sample. This kind of variation is difficult to explain at this moment. One of the reasons may be adhesion or bonding between fibers and epoxy material.

3.2 Rockwell Hardness Test

According to ASTM D 785 standards for composites, the specimens were prepared for Rockwell-B hardness test. Fiber configuration and volume fraction are two important factors that affect the properties of the composite. The hardness properties of the composites are studied by applying indentation load (Figure 6) normal to fibers diameter and normal to fiber length.

Figure 6: *Rockwell Hardness Testing Machine*

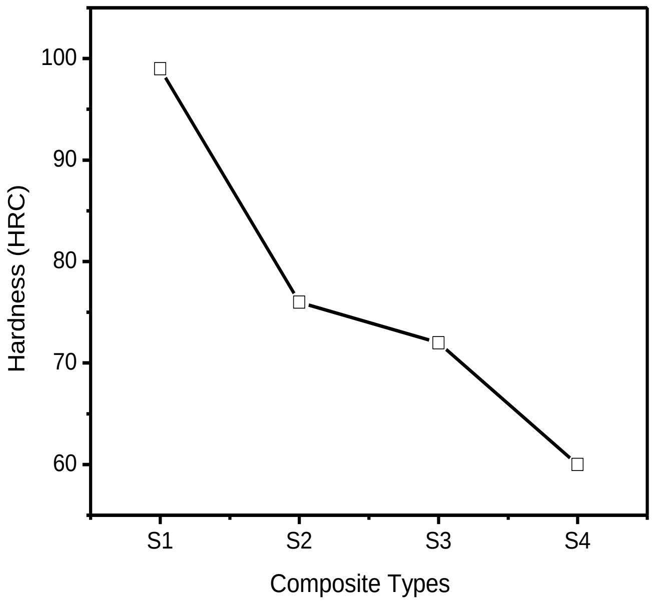

Figure 7: *Variation of Hardness with different composition*

Surface hardness of the composites is considered as one of the most important factors that govern the wear resistance of the composites. For each of the specimen surface hardness is obtained. The results are tabulated and shown in Table 2. The variations of the Hardness against various specimens are shown in Figure 7. The Figure depicts that increase in fiber loading enhances the hardness value of the sisal fiber reinforced epoxy composites. This may be due to the reason that increase in the weight percentage of the fiber, increases the ductility of the material which offers resistance for indentation.

Table 2: *Variation of Hardness*

Composition	Hardness(HRB)
S1	99
S2	76
S3	72
S4	60

3.3 Impact Test

According to ASTM D256, ISO 180 standards for composites, the specimens were prepared for Izod impact test. The impact properties of the composites are studied by applying indentation load normal to fibers diameter and normal to fiber length for various specimen types. The Izod test specimen as per ASTM standard and Test machine are show in Figures 8 respectively.

Figure 8: *Izod Testing Machine*

Figure 9: *Flexural Testing machine*

The Impact energy for various composites is obtained using above said procedure. It is interesting to note that Impact energy of the composite is found to be constant irrespective of fiber loading. The variation for various composition is shown in Table 3 and is found to be 4 Joules.

Table 3: *Variation of Impact Energy*

Composition	Energy (Joules)
S1	4.0
S2	4.0
S3	4.0
S4	4.0

3.4 Flexure test

The three-point bending flexural test provides values for the modulus of elasticity in bending and modulus of rupture. The main advantage of a three-point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate. Figure 9 Shows the Flexural Testing Machine used in our study. According to ASTM D7264 / D7264M standards for composites, the specimens were prepared for three point bending test. Fiber configuration and volume fraction are two important factors that affect the properties of the composite. The flexural properties of the composites are studied by applying load at the midpoint of span length of the specimen.

3.5 Flexural modulus of Elasticity (FMOE) and Flexural modulus

The Flexural modulus of Elasticity (FMOE) and Flexural modulus of rupture (FMOR) are obtained for various compositions using above said procedure. The variation of Load and deflections for S1, S2, S3 and S4 are plotted in Figure 10. For each composition three tests are conducted and average of FMOE and FMOR are calculated and tabulated in Table. 4.

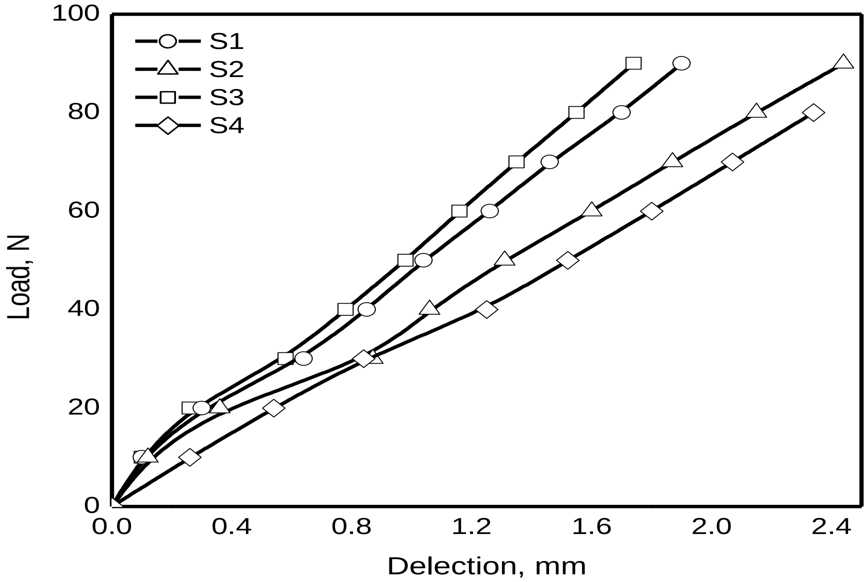

Figure 10: *Variation of Load vs Deflection*

Table 4: *Variation of FMOE and FMOR*

Composition	FMOE (MPa)	FMOR (MPa)
S1	4022.78	44.74
S2	3809.68	55.54
S3	4365.46	47.54
S4	3274.63	46.28

The variation of FMOE and FMOR for various compositions was plotted in Figure 11 and Figure 12 respectively. It is observed that FMOE is found to be more in case S3 composition and minimum for S4, where as FMOR is found to be maximum in case of S2 composition and minimum for S1.

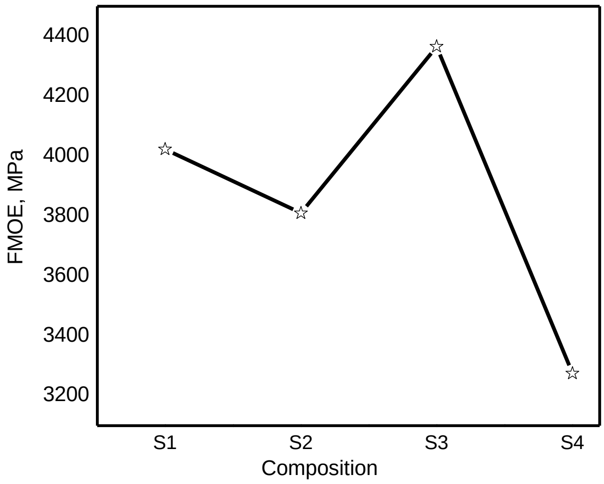

Figure 11: *Variation of FMOE for various specimens*

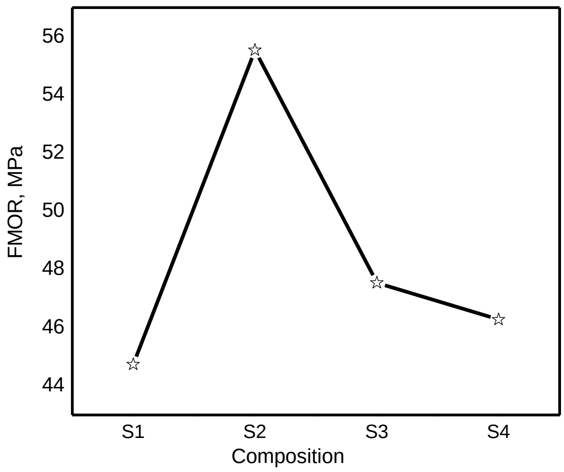

Figure 12: *Variation of FMOR for various specimens*

4. Conclusions

With the aim of development of Sisal based composites and Characterization of Mechanical Properties of Sisal Fiber Reinforced Polymer Composites have been studied. The major mechanical properties like Tensile, Hardness, Impact, and Flexural were reported. The ductility was observed to be more in case of Epoxy (90 wt%) and Epoxy (92 wt %) samples. Young's modulus was more for Epoxy (94 wt %) sample. Increase in fiber loading enhances the hardness value of the sisal fiber reinforced epoxy composites. Impact energy of the composite was found to be constant irrespective of fiber loading. FMOE was found to be more in case Epoxy (94 wt %) composition and minimum for Epoxy (96 wt %). FMOR was found to be maximum in case of Epoxy (92 wt %) composition and minimum for Epoxy (90 wt %) samples respectively.

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