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STUDY THE TENSILE AND FLEXURAL STRENGTH OF SISAL FIBER REINFORCED THERMOPLASTIC POLYURETHANE BASED COMPOSITE

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ABSTRACT

Natural fiber reinforced composites are becoming used more frequently in building materials, automobile parts, and athletic products in addition to aeronautical structures. Because of their high strength and modulus, natural fibers are receiving more attention when it comes to development and use. The present study is based on the fabrication of composites of thermoplastic polyurethane (TPU) with 10%, 20% and 30% by weight of sisal fiber (Natural fiber) using injection molding technique and testing of samples to measure the tensile and flexural strength of composites. To enhance the mechanical properties, Sisal fiber is then passed through the chemical treatment (with 8%wt NaOH and 10%wt acetone+MA) process. Chemically treated sisal fiber is then mixed with TPU as per the composition (10%, 20%, and 30% by weight) to make three samples of each composition for tensile and flexural testing. Sample fabrication has been done as per ASTM standards. The test results indicate that the tensile and flexural strength of composites is better than pure TPU. The mode of failure of samples was examined through SEM.

Keywords: Sisal Fiber, Thermoplastic Polyurethane (TPU), Composite, Tensile Strength, Flexural Strength.

I. INTRODUCTION

A macroscopic mixture of two or more different materials with a finite interface between them is called a composite material. Natural fiber composites have developed as a result of the requirement for environmentally acceptable materials or specific applications in the automotive and construction industries. The majority of natural fibers is renewable and has comparatively high strengths, stiffness, thermal stability, and other properties [1-4]. Sisal fiber is one of the more promising reinforcements for natural fiber composites, giving them increased mechanical strength. Sisal fibers are inexpensive, widely accessible, low density, have an enhanced specific strength and modulus, and are nontoxic. These fibers were utilized in the production of numerous items, including mats, clothes, purses, headgear, and ropes [5-6]. However, because of the inherent qualities of natural fibers (NFs), researchers are encountering many difficulties in the creation and use of NFPRCs. The fiber's quality, thermal stability, water absorption capability, and incompatibility with the polymer matrix are some of these difficulties [7-9]. The primary disadvantage of using natural fibers as reinforcement, however, is that their hydrophilic nature makes them incompatible with thermoplastics, leading to poor interfacial interaction between the fibers and matrix. The low mechanical characteristics of the composites are the result of this. Consequently, natural fibers need to be altered in order to reduce their hydrophilic nature. Here, a basic overview of the various chemical processes applied to natural fibers is attempted [10]. One of the most popular chemical processes for reinforcing thermoplastics and thermosets using natural fibers is the alkaline treatment. The main alteration brought about by the alkaline treatment is the breaking down of hydrogen bonds within the network structure, which increases surface roughness. Alkaline processing thus has a direct impact on the extraction of lignin and hemicellulosic components, the degree of polymerization, and the cellulosic fibril [11]. Among the various chemical treatments that are available, the Alkali/Mercerization treatment of the NF surface is thought to be an efficient one. In this therapy, a sodium hydroxide (NaOH) solution is used[12].Sisal fibre having density of 1.45g/cm^3, contains cellulose around 65-70%, Hemicellulose 12%, Lignin 9.9%, Moisture content 10%, Tensile strength 68MPa, Young's modulus 3.8GPa[13]. One class of engineering polymers with the most versatility are thermoplastic polyurethanes, or TPUs. TPUs have exceptional engineering qualities because to the hard and soft segments on its backbone and the unique hydrogen bond interactions between the hard segments, but they are also extremely complex systems to investigate[14]. Excellent abrasion resistance, outstanding mechanical qualities with rubber-like

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suppleness, and tear resistance are thermoplastic polyurethane's key characteristics. Isocyanates and polyols are the two main ingredients of polyurethane. The active group NCO of isocyanates is ready to react with hydroxyl [15]. Strong mechanical properties have been required in applications where thermoplastic polyurethane (TPU) has been employed. The polar cyanide groups on the TPU backbone chain, together with its excellent mechanical qualities, make it an excellent candidate for a matrix in the creation of an environmentally friendly, biodegradable, natural fiber composite [16-19]. In the scientific community and industry, thermoplastic polyurethane (TPU) reinforced with natural or renewable fillers has drawn a lot of attention. By utilizing various blends or reinforcements, TPU's characteristics can be modified to improve its performance and expand the composite's possible uses[20].After studying various researches, it was found that there is a scope of research on sisal fiber composites based on TPU matrix. So the research was carried out with composites of thermoplastic polyurethane (TPU) with 10%, 20% and 30% by weight of sisal fiber (Natural fiber) using injection molding technique and testing of samples to measure the tensile and flexural strength of composites. Testing results shows the improvement of mechanical properties in composites as compared to pure TPU. Also SEM was carried out to study the failure mode of composite samples after testing.

II. MATERIALS AND METHODS

2.1. Materials

Since the research deals with composites of thermoplastic polyurethane (TPU) with sisal fiber, Sisal fiber is used as reinforcement and TPU used as matrix. Sisal fiber was procured from Fiber Region Chennai, Tamil Nadu and TPU of U92 Covestro grade from Rai Innotech Polymers Pvt. Ltd, New Delhi.

2.2. Chemical treatment

First of all the cutting of raw sisal fiber was done manually in the size of 4-5mm length. To obtain the pH=7, the cut out sisal fiber was soaked for 2-3hours in 8% NaOH solution. Further the cleaning of soaked fiber was done by washing with distilled water. To dry the fiber, it was placed in oven for 2 hours at the temperature of 100-105^{0}C. After that the dried fibers were soaked in 10% Maleic anhydride (MA) solution in Acetone for 2 hours. Again the washing of MA treated fibers was done with distilled water to obtain the pH value to 7.

(a) (b) (c) (d)

Figure 1: (a) Soaking of Sisal fiber in8% wt NaOH (b) Soaking of Sisal fiber in 10% wt acetone + MA (c)Treated sisal fiber (d) Treated sisal fiber

(a) (b) (c) (d)

Figure 2: (a) TPU (b) Pure Sisal fiber (c) 8% wt NaOH treated sisal fiber 10% wt acetone + MA treated sisal fiber

2.3. Sample Preparation and testing

To test the effects of different sisal fiber contents on the tensile and flexural characteristics of thermoplastic polyurethane composites reinforced with sisal fiber, samples containing 10%, 20%, and 30% sisal fiber by weight in TPU were created. The samples were fabricated as per ASTM standards using injection moulding machine(Model: NG80, Make: Neelgiri). Three samples of each composition were fabricated for tensile and flexural testing. For samples preparation, the density of pure TPU was taken as 1.23g/cc and density of sisal fiber was taken as 1.45g/cc. The testing of samples was carried out at CIPET Murthal.

Figure 3: Samples for tensile and flexural strengthtesting of Sisal fiber reinforced TPU

2.4. Tensile test

The tensile test was conducted at CIPET Murthal, Haryana. Test was conducted on UTM (Model: AG – IS, Capacity 100KN, make: SHIMADZU).The dumbbell shaped samples(Figure 3) were prepared as per ASTM standards for the test.Gauge length of samples was taken 50mm. Three samples of each composition were prepared for the testing. The average of the strengths of three samples of same composition was considered as final strength for that composition.

a. Flexural test: Flexural test was also conducted at CIPET Murthal, Haryana. Short beam shear test (SBS) was carried out on the specimens to determine flexural strength. SBS is a three-point bend test that typically encourages interlaminar shear failure. On the same UTM, the SBS tests were also run. Three samples of each composition were prepared for flexural testing. The average of the strengths of three samples of same composition was considered as final strength for that composition.

b. Scanning Electron Microscopy (SEM): To investigate the mode of failure of tensile specimen, the Scanning Electron Microscopy(SEM) was done which is available at Chandigarh university Gharuan (Mohali).The machine has Model: JSM-IT500, Make- JEOL. Before SEM, the fractured specimen was cut in 2-3mm pieces. Then the pieces were coated with gold in smart coater machine (Model-D11-29030SCTR).To make the specimen pieces as electric conductive material, the god plating was done. Before placing the samples in SEM machine, the gold plated samples were mounted on stubs with silver paste. To get the high definition images for investigation, the vacuum was created in SEM machine. After taking images through SEM, the investigation was done to check the bonding between sisal fiber and thermoplastic polyurethane.

III. RESULTS AND DISCUSSION

3.1. Tensile strength: The tensile testing was done for the samples prepared and the results shown in table 1.

Table 1: Tensile strength of TPU + Sisal Fiber specimens

Specimen notation	Mean Tensile Strength for 3 specimens (MPa)
T0	16.92
T1	15.66

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T2	18.34
T3	16.80

Where T0 indicates pure TPU sample, T1 for sample containing 10% sisal fiber, T2 for sample containing 20% sisal fiber and T3 for sample containing 30% sisal fiber. Results shown the tensile strength of the sample (T2) having 20% sisal fiber is highest among the samples taken which provides better strength than pure TPU.

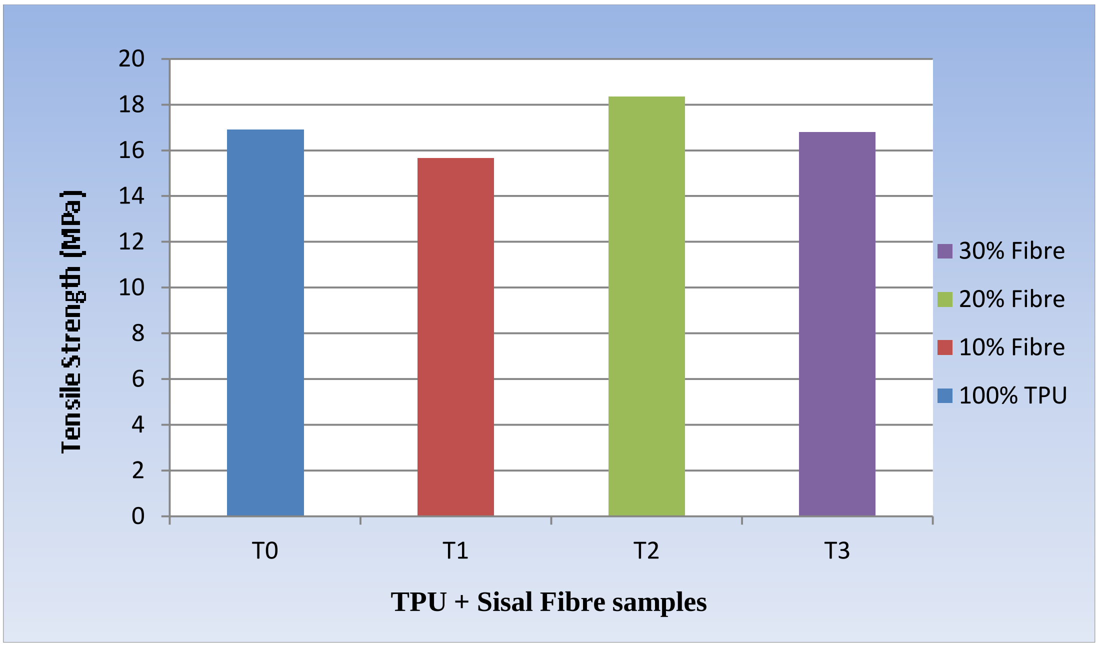

Figure 4: Tensile strength of various TPU specimens

3.2. Flexural strength: The results of the flexural strength of samples are given by table 2.

Table 2: Flexural strength of TPU + Sisal Fiber specimens

Specimen notation	Mean Flexural strength of 3 samples (MPa)
F0	6.05
F1	17.37
F2	25.6
F3	26.7

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Where F0 indicates pure TPU sample, F1 for sample containing 10% sisal fiber, F2 for sample containing 20% sisal fiber and F3 for sample containing 30% sisal fiber. Results of flexural testing of samples showing that composites of TPU with sisal fiber provides better flexural strength than pure TPU. The sample (F3) containing 30% sisal fiber and 70% TPU have highest flexural strength among the samples taken and pure TPU sample having lowest flexural strength among the samples taken for testing.

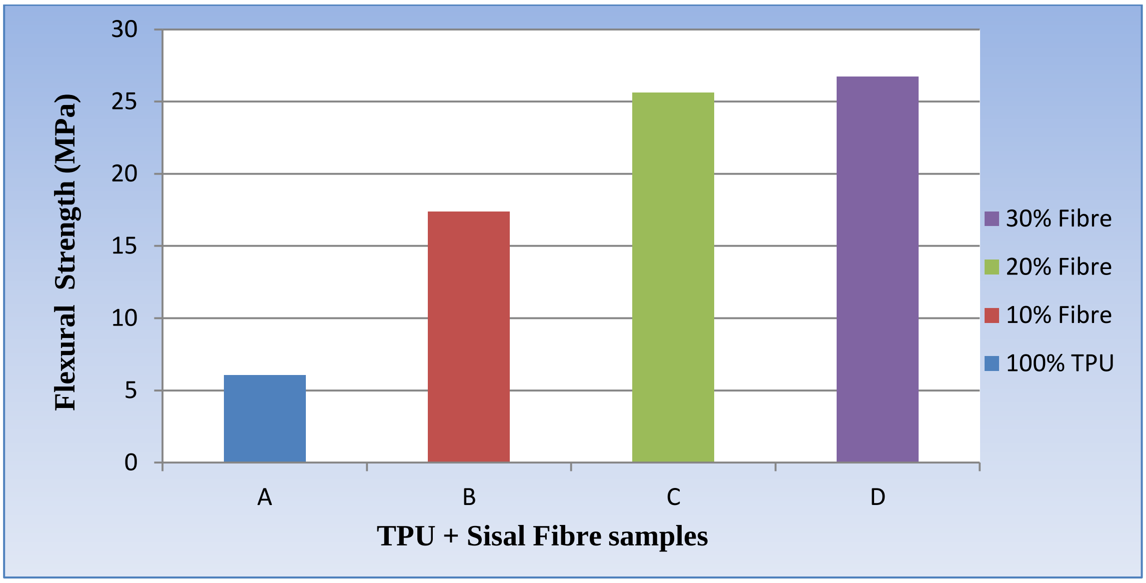
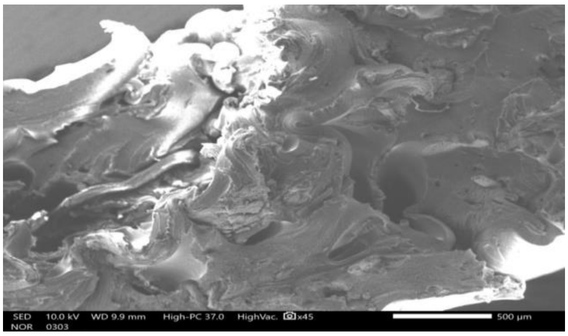
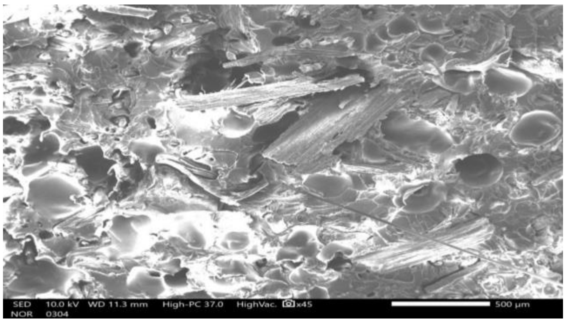


Figure 5: Flexural strength of various TPU specimens

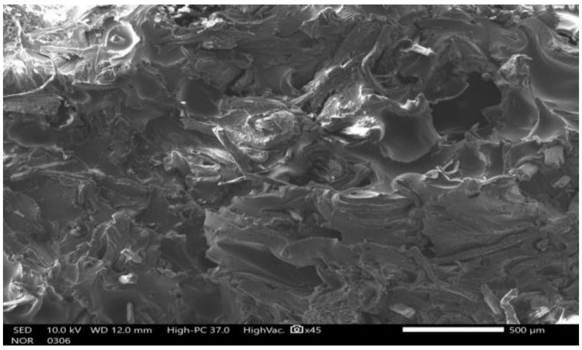
3.3. Scanning Electron Microscopy (SEM): SEM was performed to investigate the mode of failure of tensile test specimen. The high definition images of samples were taken for investigation. It examines the interfacial adhesion between TPU and sisal fiber. The images show that fiber pullout is the main reason for the failure of samples.



(a)



(b)



(c)

Figure 6: Scanning Electron Micrographs (a) 10% Sisal fiber reinforced TPU composite (b) 20% Sisal fiber reinforced TPU composite (c) 30% Sisal fiber reinforced TPU composite

IV. CONCLUSION

In this study, it is found that Composites of sisal fiber with TPU matrix are eco friendly and can be fabricated by injection moulding technique. The tensile strength and flexural strength of TPU can be changed by adding sisal fiber. The study found that the tensile strength of the composite having 20% sisal fiber and 70% TPU shows maximum strength among the composites fabricated for this study. The tensile strength of the composite having 10% sisal fiber and 90% TPU was minimum among the composites fabricated and it is also less than pure TPU. Study shows that the flexural strength of TPU can be increased by adding sisal fiber in it. The flexural strength of the composite having 30% sisal fiber and 70% TPU was maximum among the samples and pure TPU sample shows minimum flexural strength. SEM shows that fiber pullout was the main reason for the failure of samples in tensile strength testing. SEM also shows the adhesion between sisal fiber and TPU.

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