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Effect of Fiber Loading on Mechanical Properties of Borassus Seed Shoot Fiber Reinforced Polyester Composites

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Abstract
The main aim of this work is to introduce a new natural borassus seed shoot fiber as reinforcement in polymers for making partially green polymer composites. The fiber content in the composites was varied from ~ 0.116 to 0.305 by volume and the variation of mechanical properties such as tensile, flexural and impact properties in each case were studied. The tensile and flexural strength of Borassus seed shoot fiber composite have shown an improvement of 77.1% and112.6% respectively over pure matrix. The work of fracture measured in impact at maximum volume fraction of fiber is found to be 88.54 J/m. Further, the density of the composites was found to decrease with increase in fiber content.

Keywords: Natural fiber composites, Mechanical properties, Borassus seed shoot fiber, Polyester resin.

1. Introduction
The new paradigm in the preparation of fiber reinforced composites is use of natural fibers in place of petroleum-based synthetic fibers. Even though glass-fiber-reinforced composites have good mechanical properties, they exhibit shortcomings such as higher density, difficulty to machine, and poor recycling properties. Natural fibers have special advantages, such as low cost, low energy consumption, low density, high specific mechanical properties, and non-abrasive and biodegradable properties, when compared to synthetic fibers like glass. The use of natural fibers to make low cost and eco-friendly composite materials is a subject of green importance.

The development and applications of several natural fiber polymer composites have been extensively reviewed [1-9]. Different methods have been adopted to extract the fiber from elephant grass and found that in case of retting the yield of fiber was more when compared to the chemical and manual process [1]. M.C. Symington et al. [2] studied the effect of moisture content on tensile properties of natural fibers: jute, kenaf, flax, abaca, sisal, hemp and coir and concluded that the jute fiber exhibited better mechanical properties than other fibers. The low density and high porosity fraction of sansevieria cylindrical fibre is favorable for light weight applications and thermal and acoustic insulation [3]. Tensile, flexural strengths and elastic moduli of the unidirectional kenaf/PLA composites increased linearly up to fiber content of 50% [4]. Fiber extracted from waste water bamboo husk and disposable chopsticks has been used as reinforcement for making composite materials primarily for cost effectiveness and high volume applications [5, 6]. Oil palm biomass waste is a suitable material for the production of binder less particle board composite panels [7]. Tensile modulus and impact strength of rice straw reinforced composites is about 1.66 and 18 times to that of pure polyester resin, respectively [8]. The tensile properties of sisal, hemp, coir, kenaf, and jute reinforced composites have been increased with increase of fiber volume fraction [9]. Srinivas and Bharat [10] studied the impact and hardness properties of areca fiber /epoxy composite and concluded that, as the volume fraction of fiber and post curing time increased the mechanical properties of the composite increased.

Borassus is renewable and abundantly available in nature. This economical source compared to other natural sources is still under utilized. The overall objective of this work is to extract the fibers by boiling and incorporating them into polyester resin matrix to prepare the composites at various volume fractions of fiber. The composites were tested and characterized to evaluate the tensile, flexural and impact properties.

2. Experimental details

2.1. Materials

Unsaturated polyester resin of grade ECMALON 4411 was purchased from Ecmass resin pvt, Ltd, Hyderabad, India.

2.2. Extraction of fibers

Borassus seed shoot fibers were extracted from borassus young plants. Borassus young plant are cleaned and boiled in water. After boiling, we separated fibers and are dried under the sun for two days to remove moisture content. Further, the fibers were kept in hot air oven for 10 h at 70^{o} C to ensure maximum moisture removal.

2.3. Fabrication of Composites

Unidirectional composites were prepared, using polyester matrix to assess the reinforcing capacity of Borassus fibers. The quantity of accelerator and catalyst added to resin at room temperature for curing was1.5% by volume of resin each. Hand lay-up method was adopted to fill up the prepared mould with an appropriate amount of polyester resin mixture and unidirectional Borassus fiber, starting and ending with layers of resin. Fiber deformation and movement should be minimized to yield good quality, unidirectional fiber composites. Therefore at the time of curing, a compressive pressure of 0.05MPa was applied on the mould and the composite specimens were cured for 24 hours. The specimens were also post cured at 70° C for 2 h after removing from the mould. Composite samples were prepared with five different percentage volumes of Borassus fibers. The picnometric procedure was adopted for measuring the density of the composite.

2.4. Tensile and Flexural Testing

The tensile properties of the composites were measured as per the standard test method ASTM D 638 M. The length, width and thickness of the specimen were 160, 12.5 and 3 mm, respectively.

Three point bend tests were performed in accordance with ASTM D 790M test method I (procedure A) to measure flexural properties. The specimens were 100 mm long, 25 mm wide and 3 mm thick. In three point bending test, the outer rollers were 64 mm apart and samples were tested at a strain rate of 0.2 mm/min. A three point bend test was chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment. Five identical specimens were tested for each composition and all the specimens were tested at a cross head speed of 2 mm/min, using an electronic tensometer. Flexural strength (S) and modulus (E_B) in the composite was calculated using the following relationships:

$$\mathrm{S} = \frac{3PL}{2bt^2} \tag{1}$$

$$E_B = \frac{L^3 m}{4bt^3} \tag{2}$$

where L is the support span (64mm): b, the width: t, the thickness; P, the maximum load: and m the slope of the initial straight portion of the load deflection curve.

2.5 .Impact Testing

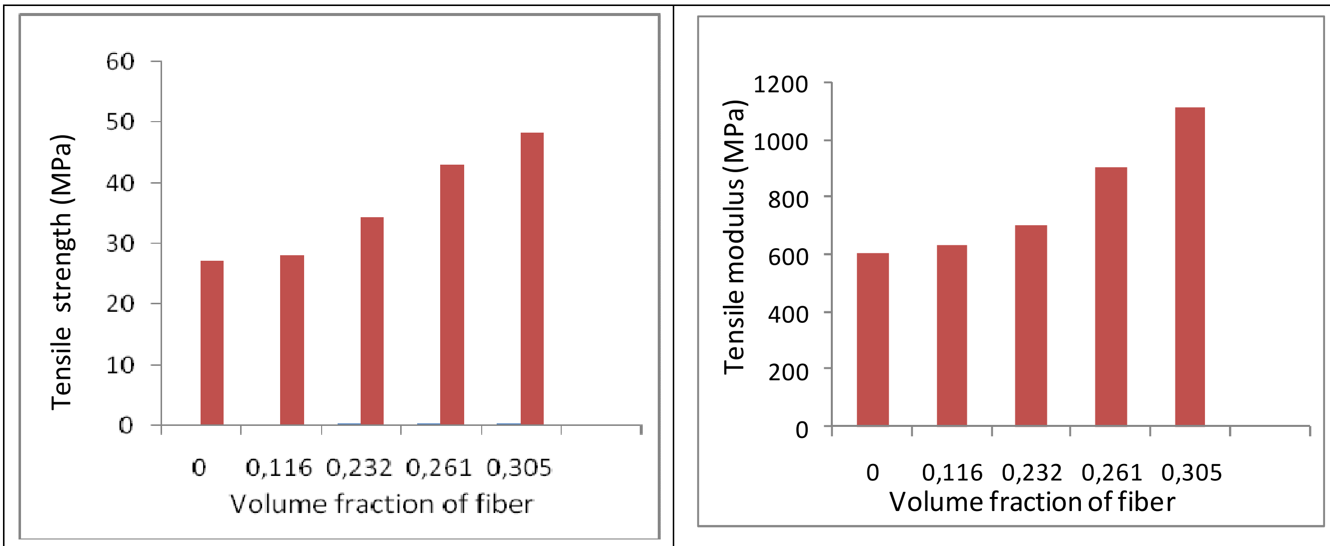
Izod impact test specimens were prepared in accordance with ASTM D 256M to measure impact strength. The specimens were 63.5 mm long, 12.7 mm deep and 10 mm wide. A sharp file with included angle of 45° was drawn across the center of the saw cut at 90° to the sample axis to obtain a consistent starter crack. The samples were fractured in a plastic impact testing machine (capacity-21.68 J), supplied by M/s International equipment, Mumbai, India. The work of fracture values were calculated by dividing the energy in Joules recorded from the tester by the width of the specimen.

3. Results and discussion

3.1. Tensile and Flexural Properties

The variation of tensile strength and tensile modulus of composite with varying fiber content is presented in Figure 1. It was clearly evident that with increasing the fiber content in the polyester matrix, the tensile strength is also increasing. This is due to the fact that the polyester resin transmits and distributes the applied stress to the Borassus fibers resulting in higher strength. Therefore, the composite can sustain higher load before failure compared to the unreinforced polyester. The tensile strength is increased by 25.67%, 57.8%, and77.1%, respectively, at 0.232, 0.261, and 0.305 volume fractions of fiber. The tensile modulus of the composites is 1.16, 1.5, and 1.85 times of the pure matrix when fiber content is 0.232, 0.261, and 0.305 by volume respectively. The tensile strength as well as tensile modulus of composite considered in this study is far better than that of peach palm fiber reinforced polyester composites [11]. Further, it was found that the failure of specimen is catastrophic without pullout of fiber from the specimen.

The flexural behavior of borassus fiber reinforced composites is presented in Figure 2. These plots exhibit the similar trend observed for tensile properties and same cause is attributed as stated above. The flexural strength of the composite at maximum fiber content is about 105.98 M P_a. The flexural strength of composite considered in this study is better than that of coir [12], and very close to banana [13] fiber reinforced polyester composites.



(a) (b)

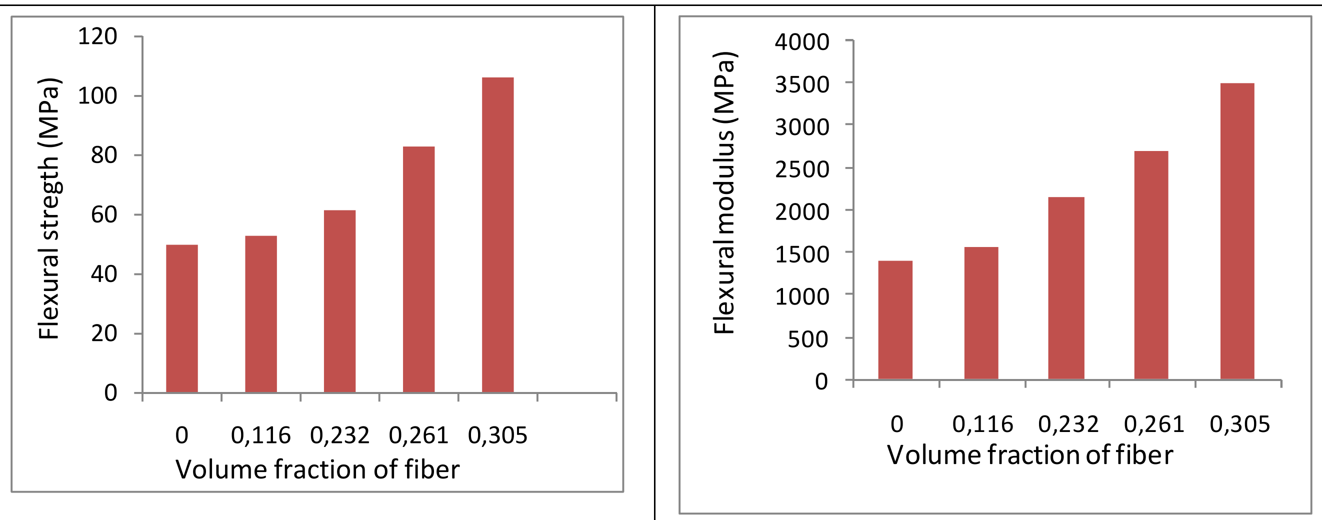
Figure 1: Variation of (a) tensile strength (b) tensile modulus of composite with volume fraction of fibre.

3.2. Impact properties

The results of pendulum impact test are shown in Figure 3(a). As the volume fraction of Borassus fiber increases, the value of impact strength increases. The composite has a work of fracture of 88.54 J/m which is about 132 % greater than that of pure polyester matrix at maximum volume fraction of fiber (0.305). The impact strength of Borassus fiber composite is in good agreement to the composites made from betel palm natural fiber [14].

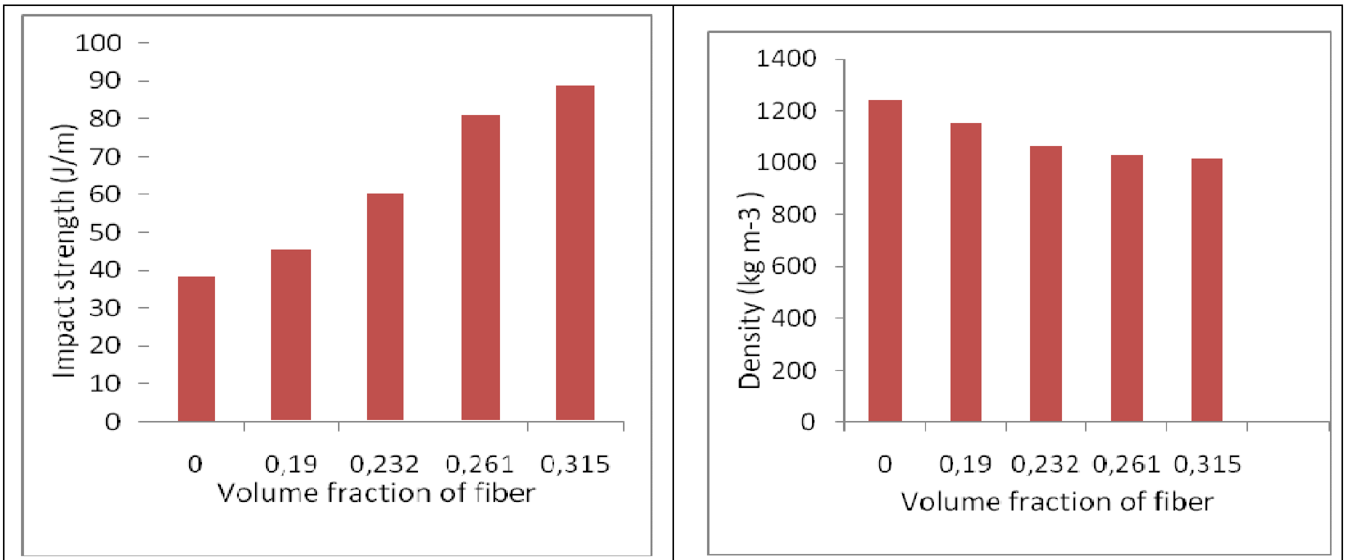
3.3 .Density of composite

The density of the composite is presented in Figure 3(b).It clearly evident that the density of the composite decrease with fiber content. Hence, it is an attractive parameter for design of light weight structures.



(a) (b)

Figure 2: Variation of (a) flexural strength (b) flexural modulus of composite with volume fraction of fibre.



(a) (b)

Figure 3: Variation of (a) impact strength (b) density of composite with volume fraction of fibre.

Conclusion

Partially green Borassus fiber reinforced polyester composites were prepared. The tensile, flexural and impact properties of the composites with these fibers were found to be higher than that of the matrix and increased with fiber content, conforming the reinforcing action of the fibers. The density of these composites was found to decrease with fiber content. Thus the composites of Borassus fiber-polyester composites were found to be light in weight, possessed better mechanical properties. Hence the newly developed composite material can be used for applications such as automobile parts, electronic packages, building construction etc.

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