

Effect of fiber content on tensile retention properties of Cellulose Microfiber Reinforced Polymer Composites for Automobile Application

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Abstract. Today, the utilization of biodegradable materials has been hogging much attention throughout the world. Due to the disposal issues of petroleum based products, there is a focus towards developing biocomposites with superior mechanical properties and degradation rate. In this research work, Hibiscus Sabdariffa (HS) fibers were used as the reinforcement for making biocomposites. The HS fibers were reinforced in the polyester resin by compression moulding method. Water absorption studies of the composite at room temperature are carried out as per ASTM D 570. Also, degradation behavior of HS/ Polyester was done by soil burial method. The HS/ polyester biocomposites containing 7.5 wt% of HS fiber has shown higher value of tensile strength. The tensile strength retention of the HS/ Polyester composites are higher than the neat polyester composites. This value increases with increase of HS fiber loading in the composites. The results indicated that HS/ polyester biocomposites can be used for making automobile components such as bumper guards etc.

1. Introduction

Recently, natural fibers like jute, hemp, banana, flax and sisal have been a part of high-tech development and began to remove their negligence. Automobile industries have got interested in new biomaterials, which can be partially decomposable or recyclable for the current global trends of the environmental protection and development of sustainable technology. The application of natural fiber composites has increased and is gaining preference over glass fiber and carbon fiber due to their low-cost and low weight characteristics [1]. Continuous efforts are on developing newer or alternative materials to achieve cost effectiveness, fuel efficiency, reduced emissions, increased safety, and always with a target on future ability to recycle or biodegrade [2]. Wotzel et al. [3] studied that the natural fiber composites were more environmentally friendly than glass fiber composite as a candidate for automobile applications. Singha et al. [4] studied the mechanical and thermal properties of Hibiscus Sabdariffa (HS) fiber reinforced phenolic resin matrix based polymer composites. Different fiber loading (in terms of weight) such as 10, 20, 30 and 40% was investigated. The result showed a general trend of increase in properties with fiber loading up to 30% and beyond this loading the properties decreases. Sonia et al. [5] investigated the extraction of cellulose microfibrils from HS fibers by steam explosion technique. Structural and surface analysis of the microfibrils showed a reduction in diameter and changes in surface morphology from that of the raw fibers. The chemical composition of fibers showed increase in α -cellulose content and decrease in lignin and hemicelluloses



for the microfibers. The effect of laccase and Xylanase enzyme treatment on chemical and mechanical properties of bananafiber was studied. The results revealed that removal of lignin content is high in laccase treatment [6]. The present study deals with the effect of fiber content on tensile retention properties of cellulose microfiber composites. Also, biodegradation behaviour of HS/ Polyester was investigated by soil burial method.

2. Materials and methods

2.1 Raw materials

Hibiscus sabdariffa var. altissima is a commercial and cheaper fiber crop known by its common name Mesta. Especially, these fibers were collected from the local cultivators of West Bengal for this study. The raw fibers were dried in an oven and they were chopped by the length of 10cm. All the chemicals such as sodium hydroxide (NaOH), sodium chlorite (NaClO₂), oxalic acid (C₂H₂O₄), epoxy resin (LY556), and hardener (HY951) (99.5% purity) used for this work were purchased from fisher scientific and HI-media, Delhi, India. The chemical treatment of raw fibres is explained elsewhere [5]



Figure 1. Various stages of microfiber extraction a) raw fiber b) bleached fiber c) oxalic treated fiber d) dried cellulose microfiber.

2.2 Extraction of cellulose microfibers from hibiscus sabdariffa var. altissima

Cellulose microfibers are extracted from HS fibers by steam explosion technique [5]. The raw fibers are collected, cleaned, washed and dried before subjected to a various chemical treatments. The figure 1 shows various stages of extraction of cellulose microfiber from HS fiber.

2.3 Composite fabrication

The composite materials are fabricated by hand layup process. The cellulose microfibers are used in the preparation of the specimen. The processed composite is pressed by Hydraulic press under 550 kPa of pressure at 100° C for 2 hours and dried for 24 hours. The composites are prepared by varying the fiber weight ratio such as 1, 2.5, 5, 7.5, 10 wt. % respectively. The epoxy resin hardener ratio is maintained at 10:1 in all formulations of composites.

2.4 Testing

2.4.1 Water absorption testing

Water absorption studies of composites such as molar percentage of water uptake, diffusion, sorption coefficient and permeability are carried out at room temperature as per ASTM D 570. Square

specimen of 30×30 mm is cut from the composite panel. In each case, five specimens were tested to obtain average value.

2.4.2 Soil burial testing

Composites are kept in a series of perforated boxes containing moisturized soil. The specimens (30×10 mm) are buried 100 mm under the surface of soil. The samples are removed at predetermined time interval and washed with distilled water. Then, it is dried at room temperature [7]. The weight loss of composite is measured using the following equation (1).

$$\text{Weight loss} = \frac{w_0 - w_t}{w_0} \quad (1)$$

where w_0 - initial mass and w_t - remaining mass at any time

2.4.3 Tensile strength testing

The tensile test of composites is carried out on Instron tensile testing machine 8801 with the cross head speed of 5 mm/min as per ASTM D638-03. Samples after water absorption (2.4.1) or biodegradation (2.4.2) are also tested to determine the tensile strength. Tensile strength retention is also determined using the following equation (2)

$$\text{Tensile strength retention} = \frac{\tau_t}{\tau_0} \times 100 \quad (2)$$

where τ_t - tensile strength after water absorption/biodegradation and τ_0 - initial tensile strength

3. Results and discussion

Tensile strength and water absorption properties of the Hibiscus sabdariffa (HS)/ polyester composites with different fibre loadings are given in Table 1. The tensile strength values of neat resin are also given in this table. The tensile strength and Young's modulus are higher for the fiber composites compared to those of the neat resin. There is an increasing trend in the value of tensile strength and modulus with fibre content can be identified from Table 1. Optimum mechanical property is obtained at 7.5% HS fiber loading after which it decreases. The improvement in tensile strength with HS fiber loading is due to the micro-level interactions. So, more effective stress transfer takes place between the components. The decrease in tensile strength at higher loading may be due to the imperfection in filler dispersion at higher loading [7]. The water uptake, diffusion and permeability values are increased with the addition of fiber due to the hydrophilic character of the natural fiber (Table 1). The neat resin has the lowest sorption value. The permeability coefficient increases linearly as the fiber loading increases from 1% to 10 wt%. Similarly, Sreekala et al. observed increased uptake of water with increasing fiber loading when cellulose fiber loading was less than 3 wt.% [8].

Table 1. Tensile strength and water absorption properties of composites.

Hibiscus sabdariffa fiber content (wt.%)	Tensile strength (MPa)	Tensile modulus (MPa)	Elongation at break (%)	Mole percentage water uptake (mole/g)%	Diffusion coefficient D ($\times 10^{-6}$) (cm ² /sec)	Sorption coefficient S	Permeability coefficient P ($\times 10^{-6}$) (cm ² /sec)
Neat	17	70	475	0.0938	0.0225	0.016	0.38
1	19	153	525	1.96	3.3	0.362	1.27
2.5	22	228	550	2.26	4.85	0.408	1.98

5	24	256	575	2.31	6.96	0.453	2.75
7.5	26	301	750	2.88	7.06	0.519	3.66
10	21	248	625	3.11	7.16	0.566	3.86

The tensile strength values of neat resin and HS fiber composites are given in the Table 2. It is understood that water absorption affects the polymer composites. The tensile strength of the neat resin and HS fiber composite are decreased after moisture absorption. The neat resin shows reduction of tensile strength values 10% and 30% respectively, at 24 and 182 h. However, fiber reinforced composites values are lower in comparison to the neat resin. This is due to the less sensitive of composites to moisture. The different retentions of tensile strength values between the composites and neat resin indicate that incorporation of HS fibers leads to an improvement in strength retention properties.

Table 2. Tensile strength retentions after water absorption and soil burial.

Hibiscus Sabdariffa Fiber loading (Wt %)	Tensile strength retention after water absorption (%)			Tensile strength retention after soil burial (%)		
	0 hr	24 Hr	182 hr	0 hr	120 hr	480 hr
Neat resin	100	90	70	100	79	65
1	100	92	75	100	81	67
2.5	100	94	82	100	83	70
5	100	96	85	100	85	73
7.5	100	98	90	100	87	75

The weight loss with degradation time is shown in figure 2. The weight loss shows an approximately linear relation with degradation time for both neat and 7.5 wt% HS fiber composites. It is observed that the weight loss of the 7.5 wt% composite is lower than that of the neat resin. The tensile strength of the neat resin and the HS fiber composite are decreased by 21% and 13%, respectively, after incubation in soil (Table 2). There is a reduction in mechanical properties of composites due to the weight loss. The composites lose their structural integrity when microorganisms consume the resin surrounding the fiber. As reported earlier [9], the attack on the HS fiber by microorganisms causes deterioration of the mechanical properties.

4. Conclusion

The mechanical properties of the Hibiscus sabdariffa /polyester biocomposites are increased as the HS fiber loading is increased up to 7.5%. The HS/polyester biocomposites have higher tensile strength and modulus than the neat polyester resin. The tensile strength of the HS /polyester composites is deteriorated after water absorption. The HS/polyester biocomposites has shown higher tensile strength retention when compared to the neat due to the higher resistance to microorganism attacks on the HS fiber. The experimental results indicated that the developed HS/ polyester biocomposites has shown better environmental protection and can be used for making automobile components.

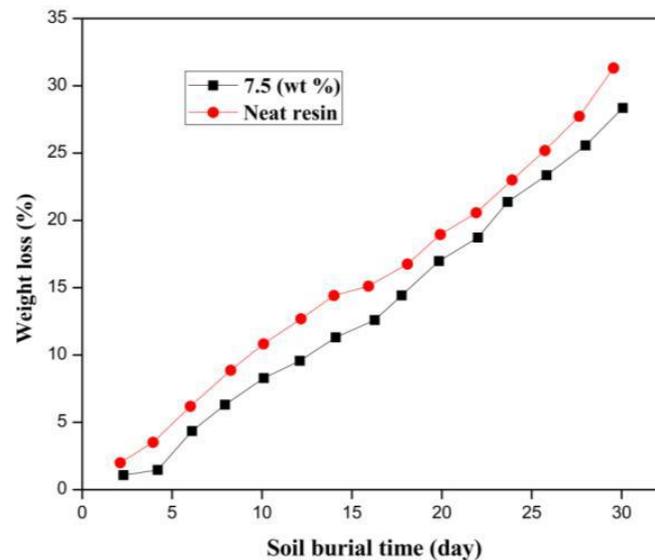


Figure 2. Weight loss as a function of time.

5. References

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