Processing and Characterization of Epoxy Composites Reinforced With Short Palmyra Fiber

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The present work explores the possibilities of using a palmyra fiber as a replacement for synthetic fiber in their application for strength purposes. Palmyra is a locally available fiber grown in tropical region of Africa and Asia. The trees are capable of growing 30m high and the leaves are fan shaped with 2 to 3m in length. An attempt has been made in the present work to improve the strength of neat epoxy composite by reinforcing it with Short Palmyra Fiber (SPF). Epoxy composites of different weight percentages of SPF (0, 2, 4, 6, 8, 10, 14 wt.%) are prepared using the conventional and economical hand-lay-up technique. The samples are subjected to tensile and flexural test using Instron 1195 universal testing machine as per the ASTM standards. The results show that with the increase in the SPF content, there is an increase in the tensile and flexural strength of the epoxy composites. Furthermore, SEM microscopy has been conducted on these samples and the results are discussed.

Index Terms— **Short Palmyra Fiber, Epoxy composites, Tensile strength, Flexural strength.**

I. INTRODUCTION

Composite materials are now-a-days being developed to replace conventional materials for many reasons such as high specific strength, higher fracture toughness, good resistance to heat/cold/moisture and ease of fabrication. In recent days as the focus is increasing on the use of environmental friendly, light weight and in-expensive materials, the possibility of using natural fibers for various applications has gained importance. Natural fiber offers several advantages such as bio-degradability, renewability, low-cost and low-toxicity. They have low density and their strength can be increased with the application of various engineering techniques on them. The present work is concerned with the processing and characterization of polymer composite reinforced with palmyra fiber (*Borassus flabellifer*). Palmyra is grown in tropical region and is native of Africa and Asia. As already mentioned, the trees are capable of growing 30m high and the leaves are fan shaped with 2 to 3m in length. A number of studies on the mechanical characterization of natural fiber composites have been reported in recent past. Sgriccia et. al. [1] characterized the natural fibers (kenaf and hemp) on the basis of flexural strength and water absorption capacity. Joseph et. al. [2] investigated the mechanical and sorption properties of polypropylene composites reinforced with jute sack cloth. Mishra et. al. [3] studied the potential of pineapple leaf fiber as reinforcement in polyester based composites. Mohanty et. al. [4] investigated the thermal and mechanical properties of MAPE treated Jute/HDPE composites. Pothan et. al. [5] analyzed the mechanical properties of banana fiber reinforced in polyester composite.

While Srinivasababu et. al. [6] described the manufacturing and characterization of long palmyra palm petiole fiber reinforced polyester composites, Wu et. al. [7] studied the characterization of mechanical and thermal properties of palm fiber-reinforced hybrid composites of poly-butylene-succinate. Similarly, Rivai et. al. [8] characterized oil palm empty fruit bunch and glass fiber reinforced recycled polypropylene hybrid composites and Velmurugan et. al. [9] elaborately evaluated the mechanical properties of palmyra/glass fiber reinforced composites. Shanmugam et. al. [10] studied the static and dynamic mechanical properties of alkali treated unidirectional continuous palmyra palm leaf stalk fiber/jute fiber reinforced hybrid polyester composites. Mahesh et. al. [11] investigated the thermal and mechanical properties of palmyra fiber reinforced polyester composites with and without chemical treatment. Prasanna et. al. [12] optimized the process for the production of banana-palmyra fiber reinforced matrix blend composites with the thermoset for the automotive and transportation industry applications.

A lot of work has been reported on polymer composites reinforced with commonly used natural fibers like jute, sisal, banana, hemp etc. But research reports on palmyra fiber based composites are only few. Though a number of studies have been conducted on reinforcement of palmyra fiber in thermoplastic polymers, there is hardly any report available on palmyra fiber reinforced epoxy (thermoset polymer) composites. A number of researches have been reported on polymers reinforced with either long unidirectional fiber or woven fiber mats, but investigations on composites with short natural fibers are limited. In view of this, the present work includes the investigation of the physical, micro-structural and mechanical characteristics of epoxy composites reinforced with short palmyra fiber (SPF) in different proportions (0, 2, 4, 6, 8, 10, 14 wt.%).

II. EXPERIMENTAL DETAILS

A. Composite Fabrication

The palmyra fiber was extracted after cutting it from the palm tree. The stalks were cut into long strips and immersed in water for a period of 10 days which is followed by drying for 5 days in sunlight. The fibers were then cut into an approximate length of 3mm with scissor. The low temperature curing epoxy resin (LY 556) and corresponding hardener (HY 951) are mixed in the ratio of 10:1 by weight. The short palmyra fiber was then mixed in various proportions to prepare the composite by hand-lay-up technique. The mixture was thoroughly mixed until uniform dough was formed. The dough was then slowly decanted into different molds so as to get disc shaped (50mm diameter and 3mm thickness) and rectangular slab specimens (150mm×100mm×3mm). Composites of 6 different weight percentages are prepared as shown in Table 1. The casting is then left to cure for about 24 hours and after that the mold is broken to get the desired specimens. Some important properties of epoxy and palmyra fiber are shown in Table 2 and Table 3 respectively.

TABLE 1 HERE

TABLE 2 HERE

TABLE 3 HERE

B. Density and Void Fraction

In the present work, the actual density (ρ_a) of composite is determined by the Archimedes principle using distilled water as the medium. This method is covered in ASTM standard D 792. According to this principle when an object is immersed in a liquid, the apparent loss in its weight is equal to the up thrust and this is equal to the weight of the liquid displaced. The density of the composite is obtained by using equation 1.

$$\rho_a = \frac{\rho_w W_a}{W_a - W_w} \tag{1}$$

Here ρ_a is the actual/measured density of composite, ρ_w is the density of distilled water, W_a is weight of the sample in air and W_w is weight of the sample in water. The theoretical density of composite materials (ρ_t) in terms of weight fraction can easily be obtained as per the following equation given by Agarwal and Broutman [13].

$$\rho_t = \frac{1}{\left(W_p/\rho_p\right) + \left(W_m/\rho_m\right)} \tag{2}$$

Where, W and ρ represent the weight fraction and density respectively. The suffix p and m stand for the fiber reinforcement and matrix material respectively. The presence of voids will add to the total volume, but not the weight of the composite. V_v is the void content which is then expressed as:

$$V_v = \frac{(\rho_t - \rho_a)}{\rho_t} \tag{3}$$

C. Tensile Strength

The cured dog bone shaped composite samples of required dimension (length 150mm, end width 20mm and mid width 12 mm) are used for the tensile test as per ASTM E 1309 standard. A uni-axial load is applied through both the ends. In the present work, this test is performed in universal testing machine Instron 1195 at a cross head speed of 10mm/min and the results are used to calculate the tensile strength of composite samples. The machine and the loading arrangement are shown below in Figure 1.

FIG. 1 HERE

D. Flexural strength

Flexural strength is defined as the maximum load that a specimen can withstand during bending before reaching the final breaking point. In the present work three point bending test method is used to calculate the flexural strength. The test is conducted on Instron 1195 universal testing machine. The dimension of each specimen is 60mm×10mm×3mm. Span length of 40mm and 10mm/min cross head speed are maintained and the results are used to calculate the flexural strength.

III. RESULTS AND DISCUSSIONS

A. Density and Void Fraction

Table 4 shows the theoretical density, measured density and void fraction in epoxy-SPF composites of different weight percentages. It can be observed that the theoretical density is greater than the measured density. This can be attributed to the presence of voids and pores present in the composite during fabrication process. It is also found that with increase in the SPF content, the density of the composite decreases from 1.1 gm/cc at 0 wt.% of SPF content to 1.089 gm/cc at 14 wt.% of SPF content but the void fraction increases from 0.454% at 0 wt.% of SPF content to 3.305% at 14 wt.% of SPF content.

TABLE 4 HERE

B. Tensile Strength

The tensile strength values of epoxy composites with different SPF content are presented in Table 5 and the variation is illustrated graphically in Figure 2. It is seen that the tensile strength which is a measure of the axial load bearing capacity of the composite increases with increase in the fiber content. With a reinforcement of 2wt% of SPF, the tensile strength of the composite is found to improve from 65MPa to 78MPa, which indicates an improvement of about 20%. Further with addition of 14wt% of SPF, the tensile strength of the epoxy composite reaches a value as high as 158MPa indicating an increment of about 143%.

TABLE 5 HERE

FIG. 2 HERE

FIG. 3 HERE

C. Flexural Strength

Similarly, the effects of SPF loading on the bending strength of the composites have also been studied in this work. Figure 3 and Table 5 present the values of flexural strength for composites with different SPF loading. A consistent rise in the composite flexural strength with increase in SPF content is recorded. It is found that while the flexural strength of neat hardened epoxy is about 58MPa, with the addition of just 2wt% of SPF it increases to about 64MPa. Similarly, with incorporation of 14wt% of SPF, the flexural strength of the composite improves by about 144% and attains a value of 142MPa.

D. Morphology of Specimens

FIG. 4 HERE

Figures 4-a, 4-b and 4-c present the surface morphology of a typical single palmyra fiber used in this investigation. It is clearly seen that the surface is uneven and exhibits a peculiar arrangement of hemispherical dots and bony ridges of different size and thickness. The surface features of epoxy SPF composite with a fiber content of 8 wt. % is shown in figure 4-d.

IV. CONCLUSIONS

Successful fabrication of epoxy composites reinforced with short palmyra fibers by hand lay-up route is possible.The void fraction is found to be increasing with the increase in the SPF content. This can be attributed to two reasons. The first reason is that with increase in the SPF content, the surface areas of the fibers are not properly wetted, thus giving rise to voids. The second reason can be due to the presence of dissolved gasses during fabrication by hand-lay-up route.Incorporation of SPF has resulted in improvement in both tensile and flexural strength of the epoxy composites and this improvement is found to be a function of the SPF content. This can be due to the increase in the load carrying capacity in axial direction with increase in SPF content.The resulting composites reinforced with an abundantly available natural fiber like palmyra have promising applications in areas like low load structures, partitions, low cost housing, insulations, etc.

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TABLE I
DIFFERENT PROPORTIONS OF SPF REINFORCED COMPOSITES

Composition
Epoxy+2wt. % SPF
Epoxy+4wt. % SPF
Epoxy+6wt. % SPF
Epoxy+8wt. % SPF
Epoxy+10wt. % SPF
Epoxy+14wt. % SPF

TABLE 2
SOME IMPORTANT PROPERTIES OF EPOXY

Characteristic properties	Inference
Density	1.1 gm/cc
Compressive strength	90MPa
Tensile strength	58 MPa
Thermal conductivity	0.363 W/m-K
Glass transition temperature	104^{0}C
Coefficient of thermal expansion	62.83 ppm/^{0}C

TABLE 3
SOME IMPORTANT PROPERTIES OF PALMYRA FIBER

Properties	Inference
Tensile strain (%)	13.71
Average tensile modulus (GPa)	2.75
Specific tensile strength (MPa)	0.3660
Specific tensile modulus (MPa)	2.67
Density (kg/m^3)	1030
Moisture content (%)	12.08

TABLE 4
THEORETICAL AND MEASURED DENSITIES OF EPOXY-SPF COMPOSITES

SPF content (wt%)	Theoretical density (gm/cc)	Measured density (gm/cc)	Volume fraction of voids (%)
0	1.1	1.095	0.454
2	1.098	1.090	0.728
4	1.097	1.085	1.093
6	1.095	1.082	1.187
8	1.094	1.078	1.462
10	1.092	1.072	1.831
14	1.089	1.053	3.305

TABLE 5
MECHANICAL PROPERTIES OF EPOXY-SPF COMPOSITES

SPF content (wt%)	Tensile strength (MPa)	Flexural strength (MPa)
0	65	58
2	78	64
4	92	73
6	112	85
8	129	99
10	152	116
14	158	142

Fig. 1. UTM Instron 1195 and the loading arrangement

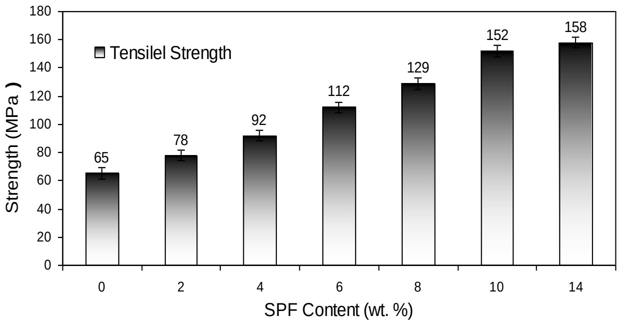


Fig. 2. Graphical representation of tensile strength

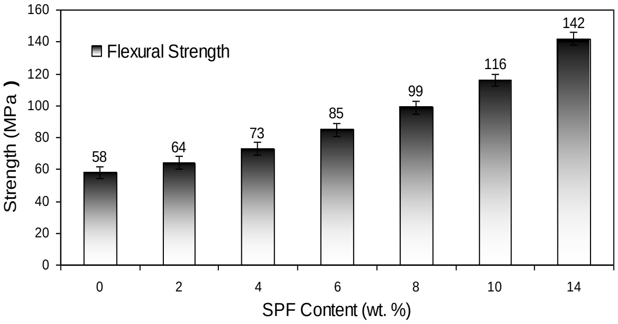
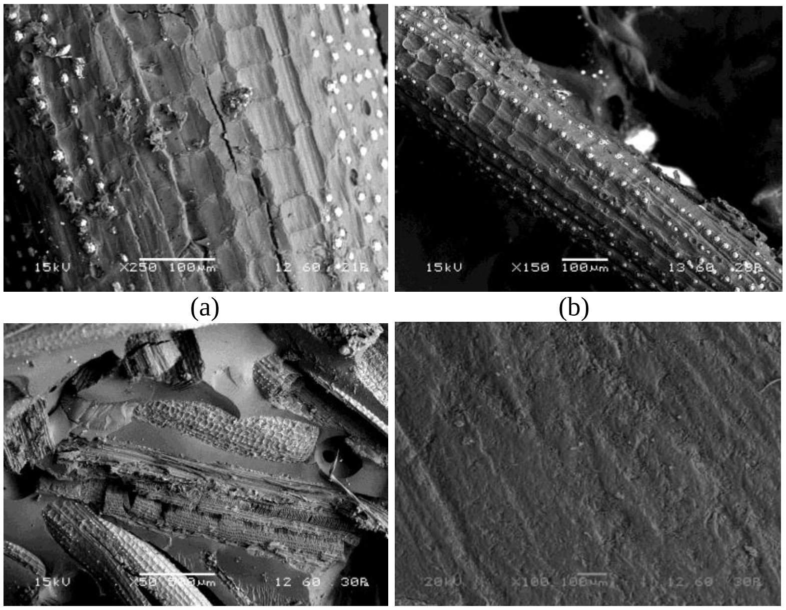


Fig. 3. Graphical representation of flexural strength



(a) (b)

(b) (d)

Fig. 4. Typical SEM images of raw fiber and epoxy-SPF composite specimen