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CHARACTERIZATION OF PALM FIBERS FOR REINFORCEMENT IN POLYMER MATRIX

Pradeep P.[1], Edwin Raja Dhas J.[2], Suthan R.[3] and Jayakumar V.[3]
[1]Department of Mechanical Engineering, Noorul Islam University, Kumaracoil, Tamil Nadu, India
[2]Department of Automobile Engineering, Noorul Islam University, Kumaracoil, Tamil Nadu, India
[3]Department of Mechanical Engineering, Saveetha school of Engineering, Chennai, Tamil Nadu, India
E-Mail: pspradeep2006@rediffmail.com

ABSTRACT

This work presents the extraction of fibers from various parts of the palm tree, its chemical and physical property characterization through standard tests and also development of composite samples with these fibers for testing tensile strength on a computerised universal testing machine. The results obtained through experimentation were compared with few other natural fiber based composites and the values were presented. The composite developed possess appreciable tensile strength and shall be used in automotive industry, aerospace applications, etc.

Keywords: palm fiber, cellulose, hemi-cellulose, density, tensile strength.

1. INTRODUCTION

Natural fibers were obtained in nature from plants (roots, stems, leaves, fruits, etc). Efforts were taken from past few decades to use natural fibers as reinforcements in polymer matrix during composite preparation. These fibers offer the potential to act as reinforcement for low to medium strength applications such as automotive, marine, electrical, industrial, etc.[1-2]. Some of the natural fibers commonly used as reinforcements were henequen [3], sisal [4], coconut fiber [5], jute [6], bamboo [7], palm [8], wood [9], basalt [10], banana [11], etc.

It is necessary to characterise plant fiber based on its cellular structure in order to use as reinforcements. The chemical structure of natural fiber or plant fiber comprises of cellulose, hemicellulose, lignin, pectin and extraneous materials. Each cell of fiber comprises of crystalline cellulose regions called microfibrils interconnected by hemicellulose and lignin fragments. Also natural fibers after treating with alkali undergo chemical modification and holds better strength there by replacing glass fibers for reinforcement in polymer matrix [12]. Investigations on the mechanical properties of composite materials reinforced with several natural fibers were studied [13-14]. Palm trees (Borassus flabellifer) available plenty in the southern parts of India has fibers from root to tip [15].

In this work fibers from various portions of the palm tree were extracted normally by retting and hand picking. The fibers chemical contents (Cellulose, hemi-cellulose, lignin and moisture) were found through standard tests. The physical properties (fiber density and tensile strength) were also calculated after testing. Composite samples were developed with each fibers and tested for tensile strength. From the test results the composite developed with palm fibers possess appreciable tensile strength and shall replace synthetic fibers for automotive applications.

2. MATERIALS AND METHOD

a) Fiber extraction

The fibers from various parts of the palm tree (leaf stalk, leaf sheath, petiole and fruit) were extracted by retting and mechanical processing like hand picking. The fibers were cleaned with fresh water and dried in natural sunlight to remove moisture content, thus uniform fibers were obtained as shown in Figure-1.

(a)Palm leaf stalk fiber (b)Palm fruit fiber

Figure-1. Extracted fibers from various parts of palm tree.

b) Composite preparation

Polyester resin along with cobalt napthanate (oxidizer) methyl ethyl ketone peroxide (catalyst) was used for preparing matrix material and extracted palm fibers as the reinforcing materials. The weight ratio of matrix (70%) and fiber (30%) were maintained. The method adopted for fabricating composite plates was normal hand lay-up process.

The fiber was placed inside the mould box (200mmx200mmx10mm) and required amount of polyester resin was poured over it, using hand rollers the air bubbles were removed. This process was continued until the composite plate with required thickness was obtained. Same procedure was adopted to fabricate samples with rest fibers.

All the composite samples were air dried at 28 °C for one day. Finally the FRP composite plates were removed from the mould and cut as per ASTM D 638 standard.

c) Testing chemical properties

Cellulose, hemi-cellulose, lignin content present in fibers has positive effects for reinforcements and were determined using standard test procedures.

The moisture content in fibers has negative effects for reinforcements and the percentage of moisture present per unit weight of each variety of fibers were evaluated by weight loss during the drying of fibers in an oven at 104 °C for 4 hrs.

d) Testing physical properties

i. Fiber density

Using pycnometer having tolune as density comparing element, the density of palm fibers was calculated using the relation as shown in Equation. (1).

$$\rho_{\text{fiber}} = \frac{(m_2 - m_1)}{[(m_3 - m_1)(m_4 - m_2)]\,\rho_t} \quad (1)$$

Where, ρ_{fiber} is the density of palm fiber (g/cm^3),
ρ_t is the density of toluene (g/cm^3),
m_1 m_2 m_3 & m_4 their respective mass (kg).

ii. Tensile strength of fibers

Using INSTRON 5500 R-type Universal Testing Machine (UTM) tensile tests was conducted on fibers with ASTM D 3822-07 standard. The fibers with gauge lengths of 30 mm, 40 mm and 50 mm were examined. A constant crosshead speed of 0.1 mm/min was used for testing all fibers. The test was conducted at (ambient temperature of 28°C and R.H. of 65%).

e) Testing tensile strength of composites

Tensile strength is a measure of force required to break a specimen and the specimen elongation before breaking. Tensile test on all composite samples were performed on a computerized servo controlled UTM. The cut specimens were placed in the grips of the UTM, whose gauge length 50mm and cross head speeds 2mm/min respectively. The samples were then pulled apart for measuring strength and elongation until the specimen got fractured.

3. RESULTS AND DISCUSSIONS

The composition of cellulose, hemi-cellulose, density and strength of fiber varies with age and the plantation environment. The properties of palm fibers in comparison with other natural fibers have been discussed in this chapter. Also the tensile strength of composite samples prepared using these fibers were discussed

a) Chemical properties

Palm fibers show the presence of high cellulose content as shown in Table-1. Cellulose content is responsible for long fiber chain and it ranges from 28 % to 53 % for palm fibers.

Table-1. Chemical properties of palm fibers.

Fibers	Chemical properties			
	Cellulose	Hemi cellulose	Lignin	Wax
	(%)	(%)	(%)	(%)
Palm leaf stalk	40–52	42–43	-	-
Palm leaf sheath	28	25	45	-
Palm petiole	30	14	28	-
Palm fruit	53	12	21	0.8
Coir	32–43	0.15–0.25	40–45	-
Pineapple leaf	70–83	-	5–12.7	-

The hemi-cellulose content of palm fibers was very low than other natural fibers. Hemi-cellulose causes disintegration of microfibrils which decrease the fiber strength and ranges from 12 % to 43 % for palm fibers.

b) Physical properties

The Physical properties of palm fibers on comparison with few natural fibers were presented in the Table-2. In general palm fiber holds appreciable fiber density and tensile strength.

Table-2. Physical properties of palm fibers.

Fiber	Physical properties			
	Density	Elong ation	Tensile strength	Young's modulus
	(g/cm3)	(%)	(MPa)	(GPa)
Palm leaf stalk	1-1.2	2-4.50	97-196	2.50-5.40
Palm leaf sheath	1.20-1.30	2.84	220	4.8
Palm petiole	0.7-1.55	25	248	3.24
Palm fruit	1.09	28	423	6.-8.
Coir	1.15-1.2	30	175	4.-6.
Pineapple leaf	0.80-1.60	14.5	144	400-627

i. Fiber density

The investigated palm fibers was found to have an average density of (0.7 to 1.55 g/cm3) which is significantly lower than widely used synthetic fibers such as E-glass fiber (2.56 g/cm3) and carbon fiber (1.4–1.8

g/cm3) but higher than other natural fibers. Figure-2 shows the density of these fibers and few natural fibers.

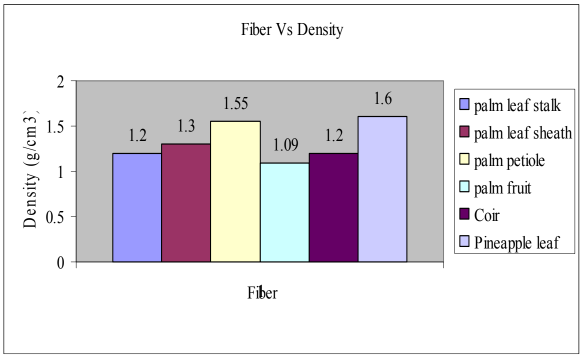

Figure-2. Fibers versus density.

ii. Tensile strength

Figure-3 shows the tensile strength of palm fibers and few other natural fibers. The tensile value of the palm fibers increases with increase in gauge lengths from 30 mm to 40 mm beyond that it decreases.

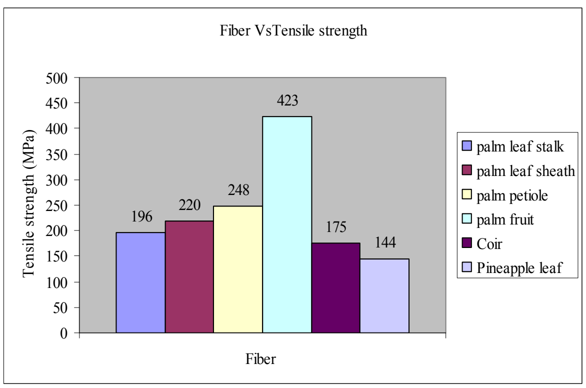

Figure-3. Fibers versus tensile strength.

iii. Tensile strength of the composites

Figure-4 illustrates the plots of tensile strength in MPa versus specimens combinations, it can be seen that the palm fruit fiber reinforced polymer composites yielded 102 MPa and holds superior values when compared with few natural fiber reinforced composites.

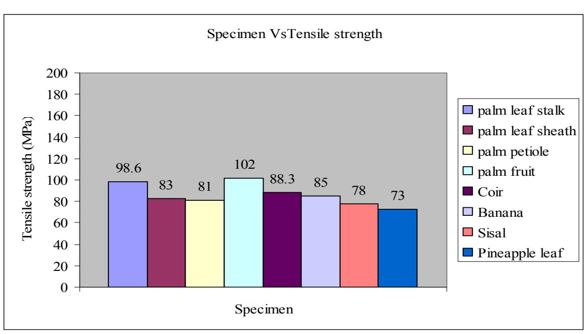

Figure-4. Composite specimen versus tensile strength.

4. CONCLUSIONS

The high rich cellulose content and lower lignin content in palm fibers ensure better mechanical strength. The tensile values of palm fibers were significantly high than any other natural fibers investigated in this study and hence it can be used for reinforcement in polymer matrix. Among all the developed composite samples the palm fruit fiber reinforced polyester composite holds appreciable tensile strength. Hence it can be concluded that the palm fibers shall be used as reinforcements in to the polymer matrix for use in various automotive industries.

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