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Effect of Alkali Treatment on Impact Behavior of Areca Fibers Reinforced Polymer Composites

Srinivasa C. V., Bharath K. N.

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***Abstract*—**Natural fibers are considered to have potential use as reinforcing agents in polymer composite materials because of their principal benefits: moderate strength and stiffness, low cost, and being an environmental friendly, degradable, and renewable material. A study has been carried out to evaluate impact properties of composites made by areca fibers reinforced urea formaldehyde, melamine urea formaldehyde and epoxy resins. The extracted areca fibers from the areca husk were alkali treated with potassium hydroxide (KOH) to obtain better interfacial bonding between fiber and matrix. Then composites were produced by means of compression molding technique with varying process parameters, such as fiber condition (untreated and alkali treated), and fiber loading percentages (50% and 60% by weight). The developed areca fiber reinforced composites were then characterized by impact test. The results show that, impact strength increase with increase in the loading percentage. It is observed that, treated areca fiber reinforcement increases impact strength when compared to untreated areca fiber reinforcement.

***Keywords*—**Lignocellulosic Fibers Composites, Areca Fibers, Alkali Treatment, Impact Strength.

I. Introduction

ENVIRONMENTAL awareness, new rules and legislations are forcing industries to seek new materials which are more environmentally friendly. Over the past two decades, lignocellulosic fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements. Unlike the traditional synthetic fibers such as glass and carbon, these lignocellulosic fibers are able to impart certain benefits to the composites such as low density, high stiffness, low cost, renewability, biodegradability and high degree of flexibility during processing.

In recent years, owing to the increased environmental awareness, the usage of lignocellulosic fibers as a potential replacement for synthetic fibers such as carbon, aramid and glass fibers in composite materials has gained interest among researchers throughout the world. Extensive studies carried out on lignocellulosic fibers such as sisal [[1]], [2], jute [[3]], [4], pineapple [[5]]–[[8]], banana [[9]]–[11], and oil palm empty fruit bunch fibers [[12]], [13] have shown that lignocellulosic fibers have the potential to be an effective reinforcement in thermoplastics and thermosetting materials.

Srinivasa C. V. is with G.M Institute of Technology, Davangere, India. (e-mail: srinikanadamani@gmail.com).

Bharath K. N.is with G.M Institute of Technology, Davangere, India. (Corresponding author; Tel: +919844400397, Fax: +918192233344, e-mail: kn.bharath@gmail.com).

According to Bledzki et al. [[14]] and Wambua et al. [[15]], lignocellulosic fibers offer several advantages over their synthetic fiber counterparts. These fibers are abundant in nature, and are renewable and low cost raw materials. Owing to their low specific gravity (about 1.25-1.50 g/cm^3 compared to synthetic fibers, especially glass fiber (2.6 g/cm^3), lignocellulosic fibers are able to provide a high strength to weight ratio in plastic materials. The usage of lignocellulosic fibers also provides a healthier working condition than synthetic fibers. This is due to the fact that, glass fiber dust from the trimming and mounting of glass fiber components causes skin irritation and respiratory diseases among workers. Besides that, the less abrasive nature of the fibers offers a friendlier processing environment as the wear of tools could be reduced.

Although there have been numerous studies on mechanical behavior of lignocellulosic fiber-reinforced composites [1]–[4], [18]–[20], only a few references are available on areca fiber-reinforced composites [17]-[19]. Among all the lignocellulosic fiber reinforcing materials, areca appears to be a promising material because it is inexpensive, abundantly available, and is a very high potential perennial crop. It belongs to the species *Areca catechu* L., under the family *Palmecea* and originated from the Malaya Peninsular, East India [[16]]. Major cultivation is in East India and other countries in Asia. In India, areca cultivation is coming up in a large scale basis with a view to attaining self sufficiency in medicine, paint, chocolate, chewable gutka, etc. The husk of areca constitutes about 60–80% of the total weight and volume of the fresh fruit. The average filament length (4cm) of the areca husk fiber is very short compared to other biofibers. Mainly two types of filaments are present – one very coarse and the other very fine. The coarse ones are about ten times as thick as jute fibers and the fine are similar to jute fiber. The fiber could be used for making value added items such as thick boards, fluffy cushions and non-woven fabrics, and thermal insulators [[17]]. The present use of this highly cellulosic material is as a fuel in areca nut processing. Unmanaged areca husk left in the plantation causes bad odor and other decay-related problems [[18]]-[19]. Therefore, extensive planning for the disposal of husk is required. Thus, the use of this unmanaged husk as structural material required a detailed study of physical, chemical and thermal characteristics [21].

In order to develop composites made from lignocellulosic fibers with enhanced strength, stiffness, durability and reliability, it is necessary to study the mechanical behavior of

Open Science Index, Materials and Metallurgical Engineering Vol:7, No:4, 2013 publications.waset.org/17126/pdf

fiber composites. The mechanical properties of a lignocellulosic fiber-reinforced composite depend on many parameters, such as fiber strength and modulus, fiber length, orientation, and fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber whereby maximum utilization of the fiber strength in the composite is achieved. Most research reviewed indicated the effect of alkali treatment in improving fiber strength, fiber-matrix adhesion and the performance of the lignocellulosic fiber composites [1], [2], [8].

Chemical modification of lignocellulosic fibers is necessary for increased adhesion between the hydrophilic fibers and hydrophobic matrix. The most promising approach seems to be one in which covalent bonds are formed between the fiber and matrix. As apparent from the above studies, one of the most common and efficient methods of chemical modification with successful results is alkali treatment of fibers [22].

Currently, there is no information on the impact properties of areca fibers reinforced melamine urea formaldehyde and epoxy resins. Therefore, this study seeks to determine the physical and mechanical properties of areca composites. A better understanding will help to develop productive uses for an empty areca fruit bunch, mitigating environmental problems from waste biomass while also developing an alternative material to wood.

II. Experimental

A. Materials

Urea formaldehyde and melamine urea formaldehyde were supplied by the Akolite Synthetic Resins, Mangalore, India. The Epoxy-556 resin and the Hardener (HY951) were supplied by Ciba Geigy India Ltd. Areca empty fruit bunch fibers (husk) were obtained from Madhu Farm House Nilogal, Davangere, Karnataka, India.

B. Fiber Extraction

Selected areca fruit husks were used to prepare the composites. Dried areca husk was soaked in deionised water for about five days. The soaking process loosens the fibers so that they can be extracted out easily. Finally, the fibers were washed again with deionised water and dried at room temperature for about 15 days. The dried fibres are designated as untreated fibres.

C. Alkali Treatment

First the areca fibers were treated in a solution of 10wt. % potassium hydroxide (KOH). The fibers were kept in the alkaline solution for 36 h at a temperature of 30°C; they were then thoroughly washed in running water then neutralized with a 2% acetic acid solution. Lastly, they were again washed in running water to remove the last traces of acid sticking to them, so that the pH of the fibers was approximately 7 (neutral). Then they were dried at room temperature for 48h to obtain alkali treated fibers.

D. Preparation of Composites

Fiber configuration and volume fraction are two important factors that affect composite properties. In the present study the following composites were prepared:

a) The composites containing 50 and 60 wt. % of alkali treated or untreated areca fibers, contained urea formaldehyde resin (UFR) and were designated as UF50 Treated, UF50 Untreated, UF60 Treated and UF60 Untreated, respectively.
b) The composites containing 50 and 60 wt. % of alkali treated or untreated areca fibers, contained melamine urea formaldehyde resin (MUFR) and were designated as MUF50 Treated, MUF50 Untreated, MUF60 Treated and MUF60 Untreated, respectively.
c) The composites containing 50 and 60 wt. % of alkali treated or untreated areca fibers, contained epoxy resin (EPOXY) and were designated as EPOXY50 Treated, EPOXY50 Untreated, EPOXY60 Treated and EPOXY60 Untreated, respectively.

The mould was polished and then a mould-releasing agent (Polyvinyl alcohol) was applied on the surface. The fibers were mixed thoroughly with the matrix materials. This mixture was left for 10 min and then the mixture was filled into the mould of 300×300×50mm. Care was taken to ensure a uniform thickness of the mat which was pressed in a hydraulic press at the room temperature and a pressure of 0.5 MPa for 30min. After that, the composites were post-cured at room temperature (27±3°C) for 24h.

E. Characterization

The prepared composite boards were post cured for 8 days at standard laboratory atmosphere prior to preparing specimens and performing mechanical tests. The appropriate ASTM methods were followed while preparing the specimens for test. At least five replicate specimens were tested and the results were presented as an average of tested specimens. The tests were conducted at a standard laboratory atmosphere of 27°C and 46% relative humidity. Impact energy absorbed by the specimens was determined by performing both Charpy and Izod method of impact testing methods as per ASTM-D256-90 with notched specimens.

III. Results and Discussion

The experimental investigation of impact properties of composites is one of the most important techniques in studying the behavior of composite materials. It has been proved that, the most effective method for studying the behavior of the materials and phase composition of fiber composites is by evaluating impact properties [1]-[3]. Impact strengths of fiber reinforced composites depend on the nature of matrix material and the distribution and orientation of the reinforcing fibers, the nature of the fiber-matrix interfaces and of the interphase region. Even a small change in the physical

nature of the fiber for a given matrix may result in prominent changes in the overall mechanical properties of composites. It is well known that different degrees of reinforcement effects are achieved by the addition of hydrophilic fibers to different polymers. This may be due to the different adhesion strengths between the matrix and fibers [21].

TABLE I
BIOMETRICAL AND PHYSICAL PROPERTIES OF ARECA FIBER

Diameter(mm)	Length of fiber (mm)				Density (g/cm^3)
	Short	Medium	Long	Average	
0.285-0.89	18-29	30-38	39-46	29-38	1.05-1.25

TABLE II
CHEMICAL COMPOSITION AND PARAMETERS OF NATURAL FIBERS [22]

Fiber	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)	Pectin (%)	Wax (%)
Jute	61-71.5	13.6-20.4	12-13	-	0.2	0.5
Flax	71-78.5	18.6-20.6	2.2	1.5	2.2	1.7
Hemp	70.2-74.4	17.9-22.4	3.7-5.7	2.6	0.9	0.8
Kenaf	31-39	15-19	21.5	4.7	-	-
Sisal	67-78	10-14.2	8-11	-	10.0	2.0
PALF	70-82	-	5-12	-	-	-
Cotton	82.7	5.7	-	-	-	0.6
Coir	36-43	0.15-0.25	41-45	-	3-4	-
Areca	-	35-64.8	13-24.8	4.4	-	-

A. Chemical Composition

The structure and chemical make-up of lignocellulosic fibers varies greatly and depends on the source and many processing variables. However, some generalizations are possible. Lignocellulosic fibers are complex in structure. They generally consist of cellulose, lignin and hemicellulose [19].

Lignocellulosic fibers are a kind of biopolymer composite, with the following components, in different proportions, depending on the species considered: cellulose, hemicellulose, lignin, and other components in small proportions. These polymers are the basic constituents of the cell wall and are responsible for most of the physical and chemical properties, such as dimensional instability to moisture, biodegradability, flammability, thermo-plasticity, and degradability by ultraviolet light, acids, and bases. All these characteristics will result in specific end use of lignocellulosics in composite formulation. Lignocellulosics can also be called *phytomass*, bio based fibers, or biofibers, including wood, agricultural residues, water plants, grass, agricultural fibers, and any other plant substance. Table II shows chemical compositions in the lignocellulosic fibers and their chemical and structural compositions of areca fibers and other lignocellulosic fibers. The total hemicellulose content of the fiber was found to be 35-64.8%, 13-24.8% lignin and a 4.4% of ash as shown in Table II [19]. Selective removal of non-cellulosic compounds constitutes the main objective of fiber chemical treatment. Both the hemicellulosic and pectin materials play important roles in fiber bundle integration, fiber bundle strength and individual fiber strength as well as water absorbency, swelling, elasticity and wet strength. The production of individual fibers without the generation of kink bands will generate fibers with much higher intrinsic fiber strength which is very useful for composite application [10], [17].

B. Impact Properties

Impact strength is defined as the ability of a material to resist fracture under stress applied at high speed. The impact properties of composite materials are directly related to its overall toughness. Fig. 1 shows the influence of the alkali treatment, different matrix materials and fiber loading on the Charpy impact strength of the areca fiber composites. The energy absorption of composite with 50 wt% areca fiber loading are 7.0, 7.25 and 9.75 Joules for untreated and 9.5, 10.25 and 12 Joules for treated fibers reinforced with urea formaldehyde, melamine urea formaldehyde and epoxy resin respectively. The percentage increase in the energy absorption capacity of composites with 60% wt of fiber loading are 12.5%, 6.45% and 4.87% for untreated and 24%, 29.31% and 45% for treated fibers, respectively. Similarly, Fig. 2 shows the variation of impact strength of areca composites under Izod impact test. It can be seen that a similar behaviors of composites can be observed as that of Charpy method. The energy absorbed by all the composites in case of Izod method is slightly less than the Charpy method of impact test. It is thus seen that with the increase in fiber content in the composite, the energy absorption improves although the increment is marginal in case of composites containing untreated fibers. Since epoxy resin has a higher molecular weight than the urea formaldehyde or melamine urea formaldehyde, the areca fibers composites show superior energy absorption capacity (more than 40%) then the areca fibers reinforced melamine urea formaldehyde or urea formaldehyde. The maximum impact energy absorption capacity of areca fibers (60% wt., treated) reinforced epoxy resin according to Charpy method is more than 34% and 40% respectively for areca fibers reinforced melamine urea formaldehyde and urea formaldehyde resin. These are 43% and 46% in the case of Izod method of impact test. From this

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work it is observed that, epoxy resin has greater impact strength when compared to urea formaldehyde and melamine urea formaldehyde.

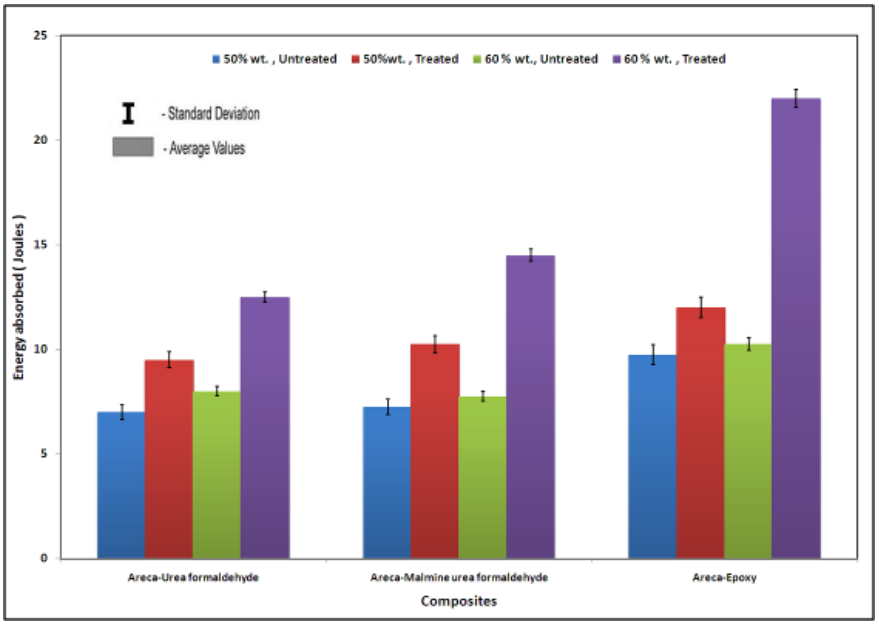


Fig. 1 Impact energy absorbed by areca composites (Charpy method)

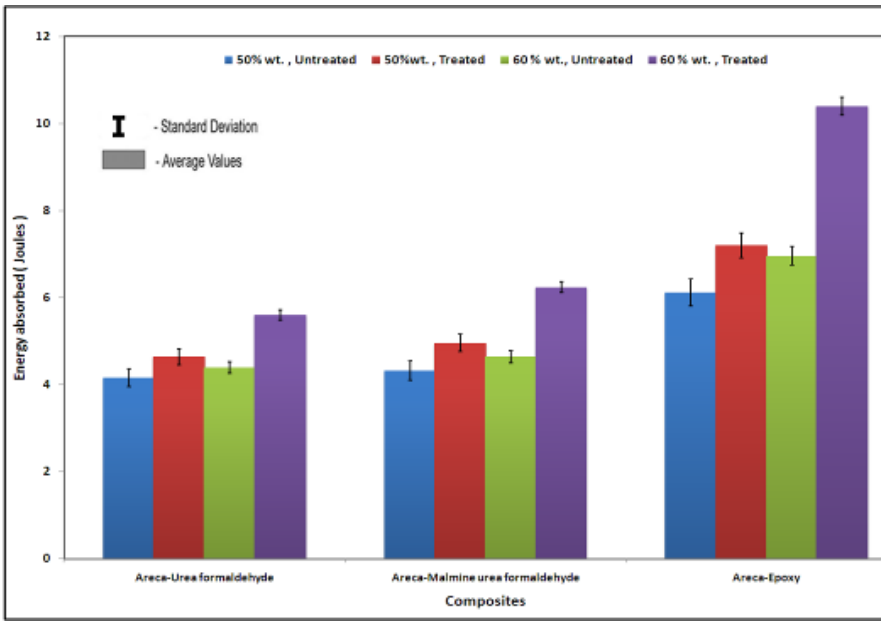


Fig. 2 Impact energy absorbed by areca composites (Izod method)

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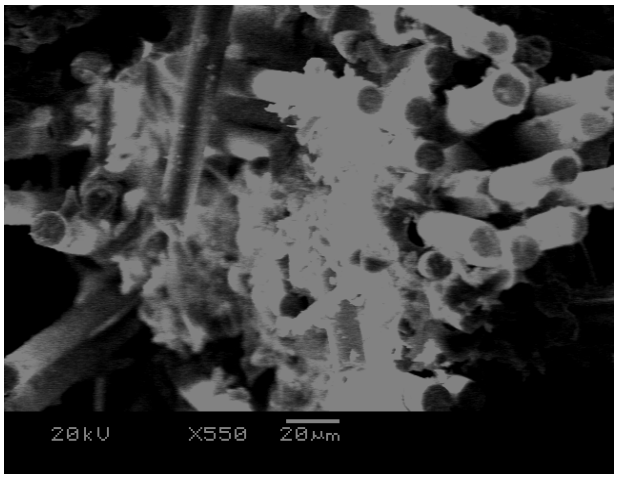


Fig. 3 Scanning electron microscopic image of fractured surface of areca fiber composite under sudden load (Alkali Treated, EPOXY60)

C. Morphological Study

SEM photographs of surfaces of composite sample EPOXY60 Treated under impact load are taken in JEOL JSM-T330A scanning electron microscope at the accelerating voltage of 20 kV. The micrograph shown in Fig. 3 shows the fractured surface of areca fiber composite (EPOXY60 Treated) under sudden load. The failure mechanism reveals that the failure was dominated by fiber breakage and slight debonding during the impact tests.

IV. Conclusions

The results presented in this work indicate that it is possible to enhance the properties of fiber-reinforced composites through fiber surface modification. Composites based on the modified fiber surface have, in general, superior mechanical properties to composites containing unmodified fibers and this, results in improved adhesion. Hence, based on the availability, low cost and good strength of areca fiber composites investigated in the present study, these composites can certainly be considered as a very promising material for the fabrication of lightweight materials used in automobile body production, office furniture, packaging industry, partition panels, etc. compared to conventional wood based plywood or particleboards.

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