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Study the Effect of Surface Treatment on the Mechanical Behaviour of Natural Fiber Composites

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Abstracts

This paper explains the effect of surface treatment on the mechanical behavior of PALF epoxy composites. The PALF fibers were given with different types of surface treatments like Alkaline, Benzoylation, Acrylonitrile. The composite were characterized in terms of tensile, flexural, impact and wear properties for both treated and untreated. Tensile and flexural tests showed that different surface treated fiber composites withstand more load than untreated fiber composites.

Keywords: PALF, epoxy, various surface treatments, mechanical properties.

Introduction

Lignocellulosic natural fibers such as sisal, coir, jute, ramie, pineapple leaf (PALF), and kenaf have the potential to be used as a replacement for glass or other traditional reinforcement materials in composites. These fibers have many properties which make them an attractive alternative to traditional materials [1]. Advantages of natural fibers over man-made fibers include low density, low cost, recyclability and biodegradability [3]. The use of composite materials in the automotive and aerospace industries is constantly increasing due to their high strength and low weight [2]. Therefore, increasingly numerous ecologically-aware studies have pointed to practical applications, such as the use of alternative environmentally-friendly materials. Natural fibers are light and renewable; they are low-cost and high-specific-strength resource. For those reasons, natural fiber composites have already been applied for fabricating some products such as furniture and architectural materials. Recently, they have gained widespread use in the automobile industry [4]

Materials and methods

Fiber preparation

PALF at present is a waste product of pineapple cultivation. Among various natural fibers, pineapple leaf fibers exhibit excellent mechanical properties. These fibers are multicellular and lignocellulosic. They are extracted from the leaves of the plant **Ananus cosomus** belonging to the Bromeliaceae family by retting. PALF fiber extracted by machine as shown fig.1

Fig. 1 Machineries Used For Extraction of PALF Fibers

The leaves of the plant are 1-1.60 m long, 5-7.5 cm width tapering to a point like sword shaped. The leaves of the pineapple produce a strong, white, fine and silky fiber. The yield of the fiber is approximately 2.5-3.5% of the weight of the fresh green leaves. Fiber has aspect

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ratio (450) 4 times higher than jute and bundle tenacity as good as sisal. Leaf is decorticated like sisal on rasp bar to extract fibers from pulp, washed and sun-dried. The fiber was chopped into 3 mm, 5mm, 7 mm and 9 mm length pieces using a sharp scissors.

Preparation of Epoxy and Hardener.

The matrix used to fabricate the fiber specimen was epoxy LY556 of density 1.13 g/cm^3 at 25°C mixed with hardener HY951 of density 0.97 to 0.99 g/cm^3. The weight ratio of mixing epoxy and hardener was followed as per the supplier norms.

Mould Preparation

The fabrication of the various composite materials is carried out through the hand lay-up technique. The mould used for preparing composites is made from two rectangular chromium-plated mild steel sheets having dimensions of 300 mm×300 mm. Four beadings were used to maintain a 3 mm thickness all around the mould plates. The functions of these plates are to cover, compress the fiber after the epoxy is applied, and also to avoid the debris from entering into the composite parts during the curing time.

Alkaline Treatment

Alkaline treatment or mercerization is one of the most used chemical treatment of natural fibers when used to reinforce thermoplastics and thermosets. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes cellulose and exposes the short length crystallites. Addition of aqueous sodium hydroxide (NaOH) to natural fiber promotes the ionization of the hydroxyl group to the alkoxide. Thus, alkaline processing directly influences the cellulosic fibril, the degree of polymerization and the extraction of lignin and hemicellulosic compounds. In alkaline treatment, fibers are immersed in NaOH solution for a period of time 1 hr with 5% aqueous NaOH solution at room temperature. It is reported that alkaline treatment has two effects on the fiber: (1) it increases surface roughness resulting in better mechanical interlocking; and (2) it increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites. Consequently, alkaline treatment has a lasting effect on the mechanical behavior of flax fibers, especially on fiber strength and stiffness. Alkaline treatment also significantly improved the mechanical, impact fatigue and dynamic mechanical behaviors of fiber-reinforced composites the tensile strength of the composite decreased drastically after certain optimum NaOH concentration.

Benzoylation Treatment

Benzoylation is an important transformation in organic synthesis. Benzoyl chloride is most often used in fiber treatment. Benzoyl chloride includes benzoyl (C6H5C=O) which is attributed to the decreased hydrophilic nature of the treated fiber and improved interaction with the hydrophobic PS matrix. Benzoylation of fiber improves fiber matrix adhesion, thereby considerably increasing the strength of composite, decreasing its water absorption and improving its thermal stability. The fiber was initially alkaline pre-treated in order to activate the hydroxyl groups of the cellulose and lignin in the fiber; then the fiber was suspended in 10% NaOH and benzoyl chloride solution for 15 min. The isolated fibers were then soaked in ethanol for 1 h to remove the benzoyl chloride and finally was washed with water and dried in the oven at 80°C for 24 h.

Acrylonitrile Treatment

A solution was made of 3% Acrylonitrile, 0.5% Hydrogen peroxide, and 96.5% ethanol (all % weight) and stirred in a covered beaker for 3 hours. The fibers were oriented in the mould placed in the solution and allowed to soak for 15 minutes. The fibers were then drained and allowed to dry under the hood for 30 minutes, then dried under vacuum overnight at ambient temperature.

Tensile test

Tensile testing of specimen prepared according to ASTM D 3039 type III sample was carried out, using electronic tensile testing machine with cross head speed of 5 mm/min and a gauge length of 50 mm. The tensile modulus and elongation at the break of the composites were calculated from the load–displacement curve. Five specimens were tested for each set of samples and the mean values were reported.

Flexural test

The flexural test was performed by the three points bending method according to ASTM D 790-03, and cross head speed of 1 mm/min. Five specimens were tested, and the average was calculated. The specimen was freely supported by a beam, the maximum load was applied in the middle of the specimen, and the flexural modulus is calculated from the slope of the initial portion of the load deflection curve.

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Results and discussion

Tensile properties

The effect of the different surface treated and untreated on the tensile performance of the short PALF fiber–epoxy composites with different fiber lengths was investigated and the displacements, engineering stress and strain, true stress and strain, load, tensile modulus were determined. Fig. 2 shows the tensile load of the composites UT3, UT5, UT7, UT9, AK3, AK5, AK7, AK9, BZ3, BZ5, BZ7, BZ9, AC3, AC5, AC7 and AC9 samples and the AC5 samples gave good results when compared with the other samples. Surface modification of the fiber by acrylonitrile treatment improved chemical bonding and helped to withstand high tensile load by the composites made of them. The sample AC5 and AC9 gave better tensile strength. This result might be attributed to a chemical structure change in the cellulose that is inherent in the fibers because cellulose molecular chains in the micro fibrils lose their crystalline structure locally as a result of the acrylonitrile treatment. This increment was attributed to the increased chemical interactions between the fiber and the matrix because of the acrylonitrile treatment. In addition, the length of fiber too might have a major role in changing the tensile properties. Among the four varying fiber lengths employed, the shortest fibers (5 mm) favored the reinforcement in the epoxy matrix in the composite showing perfect chemical bond and better interface adhesion and thus increased the tensile strength of AC

	3	5	7	9
UT	833.6	1036.3	794.4	951.3
AK	947.7	778	961.1	686.5
BZ	597.7	679.33	738	689
AC	970	1045	692	1026

Fibre Length (mm)

Fig. 2 Fiber Length Vs Load

Flexural properties

The flexural strength of the different surface treated and untreated short PALF fiber reinforced epoxy composites plotted as a function of the different fiber length (3 mm, 5 mm, 7 mm and 9 mm) is shown in Figs. 3. The fiber alkali treatment had a marginal effect on the flexural load. The AK9 sample gave better result when compared with other samples as shown in Fig. 3. The flexural strength of T3EC samples was improved by approximately 18 percent than that of UT5 sample. This indicates that there is increased area of contact between the fiber and matrix and also implies that the minimum (9 mm) fiber length enhances the mechanical components of adhesion for the matrix–fiber interfacial strength. The flexural strength was found to be greater for alkali treated composites. For an alkali treated fiber composite, the chemical bond between the fiber and matrix is superior, in turn, giving a higher interfacial stress. The flexural modulus is found to be more for alkali treated

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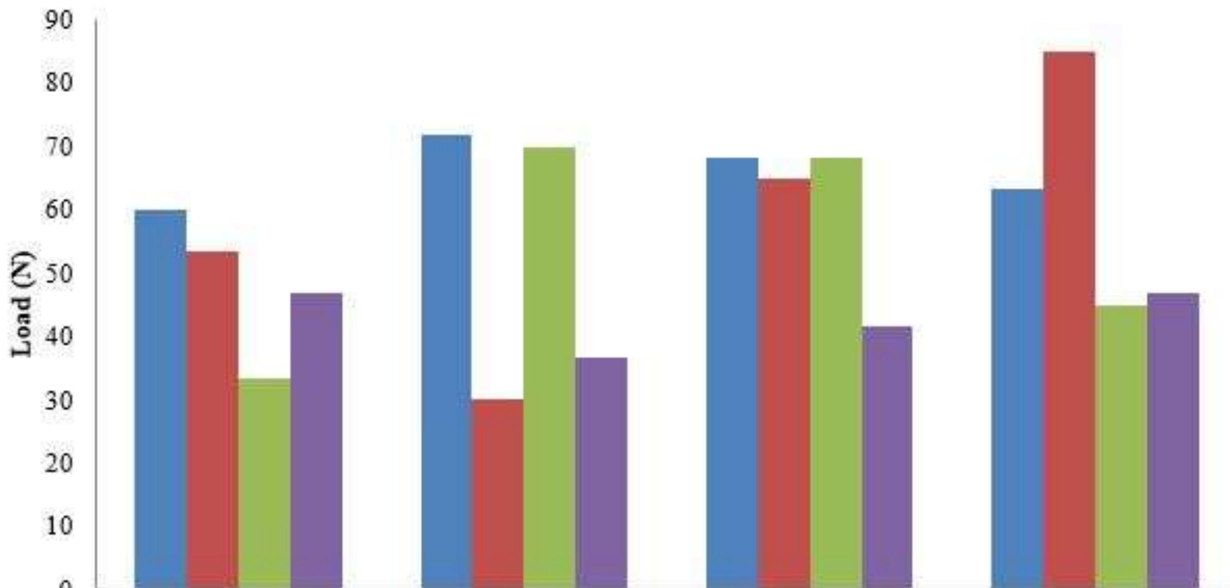
composites as illustrated in Fig. 3. Good interfacial interaction suggests that stress can transfer from the epoxy matrix to the shortened fibers very effectively during deformation, hence giving rise to higher modulus. As AK9 consist of very short (9 mm) fibers, they exhibit more flexural modulus than the other treated and untreated short PALF fiber. When the length of fiber was increased from 3 mm to 9 mm, flexural modulus gradually increased. The chemical bonding between the fibers and the matrix is probably enhanced as well, since the alkali treated fiber surface enables more hydrogen bonds to be formed between the hydroxyl groups of the cellulose on one side and the epoxy group on the other side.



	3	5	7	9
UT	60	71.7	68.3	63.3
AK	53.3	30	65	85
BZ	33.3	70	68.3	45
AC	46.7	36.7	41.7	46.7

Fibre Length (mm)

Fig. 3 Fiber Length Vs Load

Conclusion

The mechanical behaviour of short PALF fiber reinforced epoxy composites was studied. From the close results obtained for epoxy composites with untreated and alkaline, benzoylation, acrylonitrile treated PALF fibers, it can be concluded that shortest acrylonitrile treated fibers (5 mm) have good adhesion with the epoxy resin for tensile properties. In addition, the composite with alkaline treated fibers exhibited a slightly higher flexural strength than the other treated and untreated fibers. It can be concluded that surface treatment of the fibers is necessary to get composites with moderate mechanical properties as well as better adhesion between fibers and matrix.

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