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Investigations on Alkali Treated Natural Fiber Reinforced Polymer Composite by Finite Element Analysis

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Abstract

This work describes the development and characterization of a new set of polymer composites consisting of Palm leaf stalk fiber reinforcement, in polyester resin matrix. The composite slabs are made by normal hand layup process. Composites are made on pure resin using Palm leaf stalk fiber with and without alkali treatment. The newly developed composites are characterized with respect to their physical and mechanical properties. The mechanical properties like Impact strength, hardness value of the specimens were calculated by using Charpy Impact testing machine and standard hardness tester. The Palm leaf stalk fiber composites prepared without alkali treatment of the fiber showed better results. And also the finite element analysis of these Palm leaf stalk fiber composites was done using ANSYS. The analysis compares the impact strength with actual values.

Keywords: *Alkali, fiber, polyester, impact, palm, ANSYS*

INTRODUCTION

COMPOSITES OVERVIEW

Composite materials are constituents of two or more materials namely a binder or matrix and reinforcement. Usually the reinforcement material is normally stronger and stiffer as compared to the matrix and is added to enhance the property of binder or matrix. The binder also protects the reinforcement from environment. Favourable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

One of the advantages of composite is that two or more materials could be combined to take advantage of the good characteristics of each of the materials. Favourable properties of the composites motivated the researchers to make research and development in composite materials.

There are two classification systems of composite materials. One of them is based on the matrix material (metal, ceramic and polymer) and the second is based on the reinforcing material structure (particle and fiber) Among these matrix materials, the polymer composites have high stiffness, strength, toughness, design flexibility, and low density comparable with structural metal alloys and ceramics. Out of the two reinforcing materials fiber reinforcing is popular. Fiber is a class of materials that are continuous filaments or are discrete elongated pieces similar to long threads and these fibers carry the loads along their longitudinal directions, Fibers can be either natural or synthetic fibers.

The natural fiber composites can be very cost effective material for application in automotive, transportation industries and in construction industries. The main advantages of natural fiber composite include high strength to weight ratio, it is renewable, low cost for manufacturing, less wear, etc.

LITERATURE REVIEW

This chapter outlines some of the recent reports published in literature on composites with special emphasis on erosion wear behavior of glass fiber reinforced polymer composites. The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., are more often applied as the reinforcement of composites. These fibers are identified and various works are done by various researchers and scholars. The following are some of the works:

An attempt was made by K.G. Satyanarayana , K. Sukumaran, A.G. Kulkarni, S.G.K. Pillai, P.K. Rohatg to find new uses for natural fibers — one renewable resource which is otherwise under-utilized [1]. The structure and properties of the fibers, and the fabrication and physical and mechanical properties of their polyester-based composites are described. The performance of these composites is evaluated after exposure to indoor and outdoor weathering by both destructive and non-destructive testing methods. The preparation of various consumer articles such as a voltage stabilizer cover, mirror casing, a projector cover and roofing are also reported. This study demonstrates the potential of natural fibers for non-conventional applications and points out some of their limitations.

P.J Herrera-Franco and A Valadez-González studied the mechanical behaviour of high density polyethylene (HDPE) when reinforced with continuous henequen fibers (Agave fourcroydes) [2]. The alkaline treatment with matrix pre-impregnation and the addition of silane coupling agent to fibers improved the degree of fiber-matrix adhesion. The resulting strength and stiffness of the composite was proportional to silane deposition on fibers. The tensile strength attained maximum value for certain silane concentrations and further there is no increase in tensile strength when using higher concentrations. Surface modification composite did not improve the elastic modulus of the fiber. Also the tensile and flexural properties were compared with theoretical values tabulated using the rule of mixtures. Finally tensile, flexural and shear properties reveal that there is increase in stiffness of henequen fibers which was approximately 80% of the calculated values. The longitudinal direction tensile and flexural properties of the treated fibers were greater than 43% when compared with untreated fibers. The transverse direction tensile and flexural properties of the treated fibers were greater than 50% when compared with untreated fibers. The mode of failure changed from interfacial failure to matrix failure.

Coconut fiber has been used as reinforcement in low-density polyethylene. The effect of natural waxy surface layer of the fiber on fiber/matrix interfacial bonding and composite properties has been studied by M.Brahmakumar, C. Pavithranand R.M. Pillai by single fiber pullout test and evaluating the tensile properties of oriented discontinuous fiber composites [3]. The waxy layer provided good fiber–matrix bond such that removal of the layer resulted in drastic decrease of the fiber pullout stress, increase of the critical fiber length and corresponding decrease in tensile strength and modulus of the composites. The waxy layer of polymeric nature also exhibited a stronger effect on interfacial bonding than by grafted layer of a C15 long-chain alkyl molecule onto the wax-free fiber. The morphological features of the fiber along with its surface compatibility with the matrix favours oriented flow of relatively long fibers along with the molten matrix during extrusion Natural fibers (sisal, kenaf, hemp, jute and coir) reinforced polypropylene composites were processed by compression moulding using a film stacking method by Paul Wambua, Jan Ivens, IgnaasVerpoest [4]. The mechanical properties of the different natural fiber composites were tested and compared. A further comparison was made with the corresponding properties of glass mat reinforced polypropylene composites from the open literature. Kenaf, hemp and sisal composites showed comparable tensile strength and modulus results but in impact properties hemp appears to out-perform kenaf. The tensile modulus, impact strength and the ultimate tensile stress of kenaf reinforced polypropylene composites were found to increase with increasing fiber weight fraction. Coir fiber composites displayed the lowest mechanical properties, but their impact strength was higher than that of jute and kenaf composites. In most cases the specific properties of the natural fiber composites were found to compare favorably with those of glass.

Composites prepared using sisal and oil palm fibers chopped to different fiber lengths which are treated with varying concentrations of sodium hydroxide solution for different time intervals reinforced with Natural rubber was studied. Increasing the concentration of fibers reduced tensile strength and shear strength of the material, also there is increase in modulus was observed. The vulcanisation parameters, processability characteristics, and stress–strain properties of these composites were analysed. The rubber/fiber interface was improved by the addition of a resorcinol-hexamethylenetetramine bonding system. The reinforcing property of the alkali treated fiber was compared with that of untreated fiber. The extent of fiber alignment and strength of fiber-rubber interface adhesion were analysed from the anisotropic swelling measurements by Maya Jacob, Sabu Thomas K.T. Varughese [5].

Moisture absorption of natural fiber plastic composites was tested by W. Wang, M. Sain and P.A. Coope Moisture absorption of natural fiber plastic composites is one major concern in their outdoor applications [6]. Traditionally diffusion theory is applied to understand the mechanism of moisture absorption; but it cannot address the relationship between the microscopic structure-infinite 3D-network and the moisture absorption. The purpose of this study is to introduce percolation theory into this field and conduct some preliminary work. Accessible fiber ratio and diffusion-permeability coefficient determined by percolation model have been introduced in this study. At high fiber loading when accessible fiber ratio is high than at low fiber loadings, the ratio led to discrepancies between the observed and model estimates. Environmental awareness and an increasing concern with the greenhouse effect have stimulated the construction, automotive, and packing industries to look for sustainable materials that can replace conventional synthetic polymeric fibers. Flavio de Andrade Silva, Nikhilesh Chawla, Romildo Dias de Toledo Filho found that natural fibers seems to be a good alternative since they are readily available in fibrous form and can be extracted from plant leaves at very low costs [7]. In this work study on the monotonic tensile behavior of a high performance natural sisal fiber for four different gage lengths were made. The cross-sectional area of the fiber was measured using scanning electron microscope (SEM) micrographs. Weibull statistics quantified the degree of variability and the modulus decreased from 4.6 to 3.0 when the gage length increased from 10 mm to 40 mm.

C. Alves, P.M.C. Ferrão,A.J. Silva, L.G. Reis made the idea of introducing making use of natural jute fiber composites in automotive components [8]. Nowadays, the world faces unprecedented challenges in social, environmental and economical dimensions, in which the industrial design has showed an important contribution with solutions that provide positive answers regarding these problems. In particular, due to its relevance, the automotive industry confronts a moment of crises, and based on the ecodesign of products it has been transforming the challenges in opportunities. Thus, this work suggests that natural fibers like jute can be used as reinforcement which improves the environment and shall replacing the existing glass fiber in manufacturing a structural front bonnet of an off-road vehicle like Buggy. In developing nations "green" automotive components shall be produced using the developed material to make several social, environmental and economical advantages.

OBJECTIVES OF THE WORK

The objectives of the project are outlined below.

- Fabrication of Palm leaf stalk fiber polyester matrix composite with/without alkali treatment.
- Evaluation of mechanical properties (Impact strength, Hardness value).
- FEA based analysis of impact strength.

Besides the above all the objective is to develop relatively low cost composites by incorporating cheaper reinforcing phases into a polymeric resin. Also this work is expected to introduce a new class of polymer composite that might find applications in erosive operational situations for car underbody shield.

MATERIALS AND METHODS

Introdution

This chapter describes the details of processing of the composites and the Experimental procedures followed for their characterization and tribological Evaluation. The raw materials used in this work are

1. Palm leaf stalk fiber
2. Polyester resin

Processing Composites

Palm leaf stalk fibers are reinforced in unsaturated isophthalic polyester Resin to prepare the composite. The composite slabs are made by conventional compression moulding Technique. Two percent cobalt nephthalate (as accelerator) is mixed thoroughly in isophthalic polyester resin and then 3% methyl-ethyl-ketone-peroxide (MEKP) as hardener is mixed in the resin prior to reinforcement. Composites are made on pure resin with Palm leaf stalk fiber under random orientation (arrangement of fiber in the composites). The castings are put under load for about 3 to 4 hours for proper curing at room temperature. Similar procedure adapted for the preparation of the alkali treated Palm leaf stalk fiber polymer composites.

Characterization of the Composites

Impact Test

Impact tests are designed to simulate the response of a material to a high rate of loading and involve a test piece being struck a sudden blow. Here the impact test was conducted using charpy impact tester. The charpy impact test, also known as the charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. First the specimens were cut as per ASTM D 695.

The test was conducted on a charpy impact testing machine shown in Figure. Then the specimen was held such that the specimen rests against two supports on either side of the test notch. The test involves a pendulum swinging down from a specified height h0 to fit the test piece and fracture it. The pendulam struck directly behind the test notch such that the specimen undergoes three point bending. The height h to which the pendulum rises after striking and breaking the test piece was a measure of the energy used in the breaking. If no energy were used the pendulum would swing up to the same height h0 it started from, i.e. the potential energy mgh0 at the top of the pendulum swing before and after the collision would be the same. The greater the energy used in the breaking, the greater the loss of energy and so the lower the height to which the pendulum rises. If the pendulum swings up to a height h after breaking the test piece then the energy used to break it is mgh0 – mgh. Figure shows the ASTM D 695 standard charpy impact specimens with notch.

***Fig. 1:** Charpy Impact Testing Machine.*

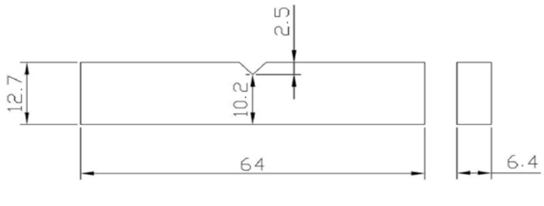

***Fig. 2:** ASTM D 695 Standard Impact Specimens.*

Hardness Test

It is a fundamental property which is closely related to strength. Hardness is usually defined in terms of the ability of a material to resist scratching, abrasion, cutting, indentation, or penetration. It is important to note that the hardness of a metal does not directly relate to the hardenability of the metal. Many methods are now in use for determining the hardness of a material. They are Brinell, Rockwell and Vickers.

The investigation was done using Rockwell hardness tester shown in Figure. The Rockwell hardness test is based on the indentation of a hard tip, or indenter, into the test piece under the action of two consecutively applied loads – minor (initial/0 and major (final). In order to eliminate zero error and possible surface effects due to roughness or scale, the initial or minor load is first applied and produces an initial indentation.

A conical shaped diamond (called a brale) with 120^0 apex angle and 0.2 mm radius is used as the indenter or penetrator in the Rockwell test for hard materials. For softer materials, a hardened steel ball 1.5 mm in diameter is generally used.

A number of different scales are used, each scale being suitable for certain classes of materials. It should be understood that each scale is entirely arbitrary, the hardness number obtained having relevance to that particular scale only. For polymer R and M scale are commonly used.

After loading, the major load is removed. The Rockwell hardness number is the difference in depths of the indentations made by applying the major and 10 kg minor load, measured after removing the major load. Figure also shows the hardness determination with a diamond cone (brale) in a Rockwell test. The number 1-1 indicates the penetration of the cone under the minor load, 2-2 indicates the penetration of the cone under the major (final) load, and 3-3 indicates the penetration of the cone after major load is reduced again to the value of the minor load.

The load was applied and maintained for up to 15 seconds and then released, the hardness number then being read off the scale graduated in hardness units to the nearest whole number. Figure shows the ASTM D 785 standard specimen for hardness test

Palm Leaf Stalk Fiber

Shrub like palms often have such short stems that the leaves seem to rise directly from the soil. The stems of some kinds of viny palms creep along the ground; some climb on upright plants. The climbing stems of the rattan palms may reach a length of more than 600 feet (180 m). The flowers and fruit of a palm are borne in or near the crown of leaves. Small greenish or yellow flowers are clustered on a spike or on a branching axis (stalk). Palm leaves are large and shaped like fans or feathers.

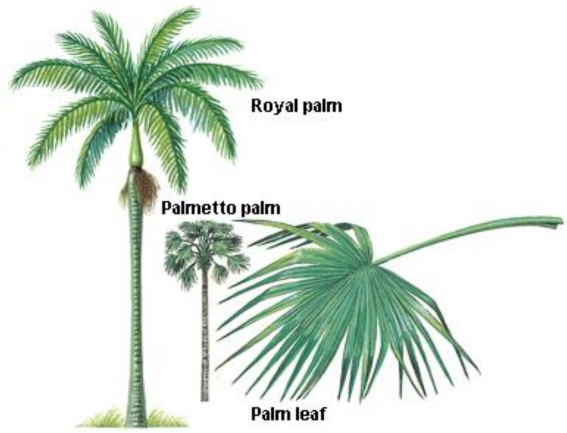

Fig. 3: *A Typical Palmyra Tree Showing the Leaf Stalk.*

These leaves are generally used for preparing essential things like mats, umbrellas, baskets, hats, hand held fans, etc. It was used as writing material by stripping into small rectangular sheets. A variety of rice flour cake was prepared using these leaves in some countries.

MATERIAL PREPARATION

Required materials are Palm leaf stalk fiber, polyester resin. Palm leaf stalk fiber are extracted from leaf stalk of the palm tree, Polyester resins are produced by the poly condensation of saturated and unsaturated dicarboxylic acids with glycols.

Extracting the Fiber

Fiber is extracted by a process known as decortication, where leaf stalks are crushed and beaten by a rotating wheel set with blunt knives, so that only fibers remain. Proper drying is important as fiber quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fiber than sun drying.

Fig. 4: *Palm Leaf Stalk Fiber.*

Polyester Resin

Polyester resin is yellowish tint in colour when mixed with hardner like methyl ethyl ketone peroxide it decomposes to generate free radicals and gets hardened over time. It is suitable for most of the applications like sheet moulding, bulk moulding, laser printers toners, wall panels, etc. The resin when reinforced with fiberglass termed fiberglass reinforced plastic (FRP) are typically used in interior designing of restaurants, kitchens, restrooms and in areas that require washable low-maintenance walls. It is also used in the making of surfboards and in marine applications. The resin is UV sensitive and can tend to degrade over time, and a protective coating is needed to preserve it.

Alkali Treatment

There are several different methods for modification of surface energy of the fiber and the polymer. Physical methods like stretching, calendaring and the production of hybrid yams, change the structural and surface properties of the fiber and thereby influence the mechanical bonding in the matrix. Another physical method used is electric discharge, which will increase the roughness of the fibers and active its surface oxidation leading to the increase in aldehyde groups. It can also generate cross linkings and free radicals. Oxidizing agents such as Na or Ca and hydrogen peroxides can be used to remove dust and oil from natural fibers. Alkaline treatment with NaOH, known as mercerization, extracts lignin and hemicelluloses, increasing the tensile strength and elongation at break of the composite. In this process the fibers are immersed in 4% solution of NaOH for 1 to 2 hours, followed by continous washing and drying in room temperature.

FABRICATION OF FRP

Fabrication of the FRP involves the following steps

- Set the molding board on which the fabrication is to be done.
- Then, clean the surface of the worktable with wax polish; this acts as a releasing agent which helps in the easy removal of the final product.
- Now, construct the frame with the required dimensions, as follows: Length=280 mm, Width=200 mm, Thickness=15 mm
- Next, apply polyvinyl alcohol over the wax polish on the surface of the board; this also acts as a releasing agent.
- Then a polyester resin coating is applied to the constructed frame.
- Then, the fibers are applied to the frames according to the length. (From 0.5cm to 1.5 cm). Then, the required amount of the polyester resin is added to each of the frames according to the specified percentage.
- Then, the whole work board is placed in the sun for it to set.
- After the polyester resin has set, the pieces are cut out from their frames according to the standards.

SPECIMENS FOR TESTING

Hardness Test Specimen

Fig. 5: *Hardness Testing Specimen.*

Impact Testing Specimen

Fig. 6: *Impact Testing Specimen.*

RESULTS AND DISCUSSION

Mechanical Properties of Composites

The characterization of the composites reveals that inclusion of alkali treatment has strong influence on the physical and mechanical properties of composites. The modified values of the properties of the composites under this investigation are presented and compared against the untreated palm leaf stalk polyester composite. A gradual increase in impact strength as well as flexural strength with the weight fraction of fiber is noticed. It can be clearly seen that treated fiber shows increase in performance comparing the untreated one. It may be mentioned here that both tensile and flexural strengths are important for recommending any composite as a candidate for structural applications. From the obtained results of the tensile testing of the palm leaf stalk fiber it can be noted that there is difference in their properties between the alkali treated and non-treated fibers.

Impact Strength

The impact test namely charpy and izod were carried out and the values were noted after testing both the alkali treated and non treated palm leaf stalk fibers. The results showed that there is difference in energy value between the alkali treated and non alkali treated palm leaf stalk fibers.

Table 1: *Impact Test Results.*

S. No.	Specimen	Energy(J/mm^2)
1	A	0.222
2	B	0.183

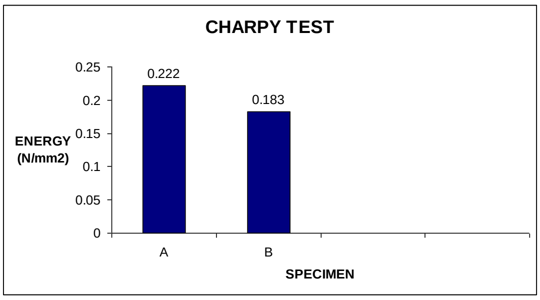

Fig. 7: *Graph Showing Impact Strength Values.*

Hardness Value

The hardness value was noted after testing both the alkali treated and non treated palm leaf stalk fibers. The results showed that there is difference in hardness value between the alkali treated and non alkali treated palm leaf stalk fibers.

Table 2: *Hardness Test Results.*

S. No.	Specimen	Rockwell Hardness no
1	A	56
2	B	60

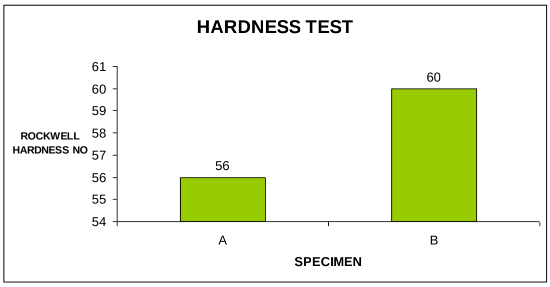

Fig. 8: *Graph Showing Hardness Values.*

TEST RESULT FOR ANSYS

The test is generally performed on ASTM specimens. The commonly used specimens for tensile test are rectangular type with a v notch at centre. During the test a uni-axial load is applied through the centre of the specimen and its ends displacement were constrained. The test results such as Stress, Strain and Displacement are analyzed.

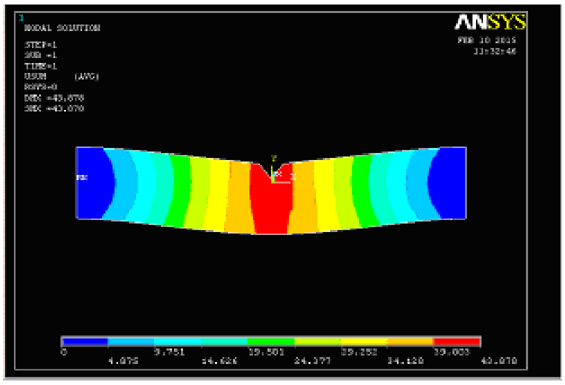

Fig. 9: *ANSYS Result on Impact Specimen.*

CONCLUSION

This analytical and experimental investigation on the palm leaf stalk polymer composites leads to the following conclusions:

- This work shows that successful fabrication of palm leaf stalk polymer composites with and without alkali treatment by hand layup process.
- The cheaper natural fiber like palm leaf stalk fiber can be used to make an effective fiber polymer composite.
- The performance of the non treated palm leaf stalk fiber was found to be superior to the treated palm leaf stalk fiber.
- From both the impact and hardness test the non treated palm leaf stalk fiber was found to be superior to the treated palm leaf stalk fiber.
- The experimental results were compared with the ansys result and found to be equal.

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