Mechanical properties of surface treated coir fiber composite materials

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Abstract __ Considerable research in the field of material science has been directed towards the development of new, light weight, high performance engineering materials like composite. Attention has been focused in the development of natural fiber composite due to their low cost and biodegradability. Composite specimens using coir fibres as reinforcement in a polymer matrix are fabricated by compression moulding process. The specimens are prepared, by reinforcing alkali treated fibres with different fiber length and with different weight percentage. The mechanical property of the composites like tensile, flexural and impact strength is determined as per ASTM standards. The regression models of tensile, flexural and impact properties were developed using Minitab. The optimum fiber parameters for maximum mechanical properties were determined. The results showed that the fiber content in weight percentage is playing major role than the fiber length on the improvement of tensile, flexural and impact strength properties.

Keywords___ Coir fiber, surface treatment, mechanical properties, composites

I.INTRODUCTION

Coir is a versatile fiber obtained from coconut trees (cocos nucifera) which grow extensively in tropical countries. The limitations of using lingo cellulosic fibers as reinforcement in polymer matrix composites is the poor interfacial strength developed between the hydrophilic fibers and the hydrophilic matrices. To overcome this several physical and or chemical treatments were developed in order to ensure a better fiber-matrix interaction [1]. Composite products have good mechanical properties per unit weight, durable and their technologies allow manufacturing of complex and large shapes [2]. Jeyabal et al. [1] said that the fiber length also plays a main role and they obtained higher value of mechanical property using continuous coir fiber and optimized using statistical package software. Sree Kumar et al. [2] treated sisal fibers with various chemicals and examined the mechanical properties. They concluded that surface treatment improves the properties of fibers. Herrera–franco [3] examined continuous henequen fibers by surface

Modifications using alkaline treatment together with a silane coupling agent. He found that the tensile strength did not improve due to use of silane concentrations. Sinha et al. [4] made an effort by varying the treatment time using jute fiber and find as the treatment time improves the flexural properties. Velumani et al. [5] experimented alkali treated coir polyester composites. The surface treatment improves the adhesion between fiber and matrix. He observed the fiber length and weight plays a significance role in mechanical properties. Velmurugan et al. [6] reported addition of glass fiber with Palmyra fiber gives a better result in tensile, flexural and shear strength. Tharanitharan et al. [7] examined coir sisal hybrid composites. He used vinyl ester resin and samples made by hand layup process. The different combinations are carried using design of experiments and mathematical models also developed to optimize the fibers. Athijayamani et al. [8] used roselle and sisal fibers to produce hybrid composites also glass fiber composite is produced to compare the properties. This investigation also reports that increasing fiber length and content will increase the mechanical properties. Since most literature cover only a specific work on fibers, this work was aimed at analyzing of tensile strength of treated coir fiber composites covering a large range of fiber length and fiber content. The mathematical model was developed using Minitab to find the optimum fiber parameters and their influence on maximum tensile strength was studied in this work.

II.EXPERIMENTAL

A. Fiber preparation

The coir fibers are mechanically extracted from the green husk of coconut after soaking the husk in water. The green husk fiber bales are soaked in water for 3–7 days to remove the colouring matter and to make the fibers soft. The fibers were cut for the dimensions of 50, 100, 150 and fiber content in weight percentage of 15, 25, and 35 respectively. The properties of treated coir fiber shown in table I

Table I Properties of treated coir fiber

Properties	coir
Cellulose (wt %)	34-47
Hemi cellulose	0.15-0.25
Young's modulus (Gpa)	4-7
Tensile strength (Mpa)	129-182
Lignin (wt %)	0.4-0.29
Density (gm/cm³)	1.28
Fiber diameter (mm)	0.072-0.212

B. Surface modification of fibers

The coir fibers were treated with 5% NAOH solution for 30 min. The fibers were then washed with very dilute hydrochloric acid to remove the traces of alkali. The fibers were washed many times using water were they are free from alkali. The fibers were dried in an air oven at 70°c to remove moistures.

Fig. 1 Surface treatment of fibers

C. Fabrication of composites

Initially the treated fibers were spread horizontally and randomly. Polyester resin was used as matrix material. Matrix material consists of unsaturated polyester resin, cobalt naphthalene (accelerator), and MEKP catalyst in the ratio of 1:0.015:0.015. For easier removal of composite sheets from the mold, polyvinyl acetate was sprayed on the mold surfaces before the mould. The fibers and resin were poured in the mold frame of size 200 mm x200 mmx3 mm and pressed by compression moulding process for 6 h. After it the composites were removed from the mold and cured at room temperature for 24 h. The same procedure was followed to fabricate various combinations of fibers. The fabricated plate is shown in figure. 2. After curing, the composite sheets were cut according to ASTM standards.

Fig. 2 Fabricated composite plate

III. MECHANICAL TESTING

A. Tensile strength test

The tensile strength was determined according to ASTM 638-08 standards. The length, width and thickness of each sample were approximately 165mmx25mmx3mm. For this testing the composites were cut into five identical specimens were tested and average result was derived. The tensile strength for the nine combinations of various fiber parameters are shown in table II. The specimens were tested in Instron tensile testing machine with a cross head speed of 5mm/min. Figure .3 and 4 shows the specimen which is used to find the tensile strength.

Table II Mechanical property of treated coir composites

Sample Identification	Fiber length (mm)	Fiber content (%)	Tensile strength (Mpa)	Flexural strength (Mpa)	Impact strength (J/m)
50-15	50	15	13.8	22.4	25.6
50-25	50	25	16.1	29.3	48.5
50-35	50	35	14.1	26.4	87.5
100-15	100	15	10.6	25.9	109.6
100-25	100	25	13.6	31.6	130.5
100-35	100	35	11.6	26.7	151.3
150-15	150	15	12.8	31.7	64.5
150-25	150	25	15.6	38.5	104.4
150-35	150	35	13.5	34.8	161.9

Fig. 3 Photograph of specimens before tensile testing

Fig. 4 Photograph of specimens after tensile fracture

B. Flexural strength test

The rectangular test pieces of 127×12.7×3 mm dimension for flexural test were cut from the prepared composites. Flexural test was conducted as per ASTM D 790 standards. The test was conducted on the Instron machine with Series IX software using a load cell of 10 KN at 2.8 mm/min rate of loading. The Specimen was freely supported by a beam, and the load was applied in the middle of the specimen. The tests were carried out at a temperature of 27°C and the relative humidity of 50%. For statistical purposes, a total of five samples were tested. Figure .5 and 6 shows the specimen which is used to find the flexural strength.

C. Impact strength test

The Un notched test pieces of 80x10x2 mm dimension for impact test were cut from the prepared composites. Impact test was

Fig. 5 Photograph of specimens before flexural testing

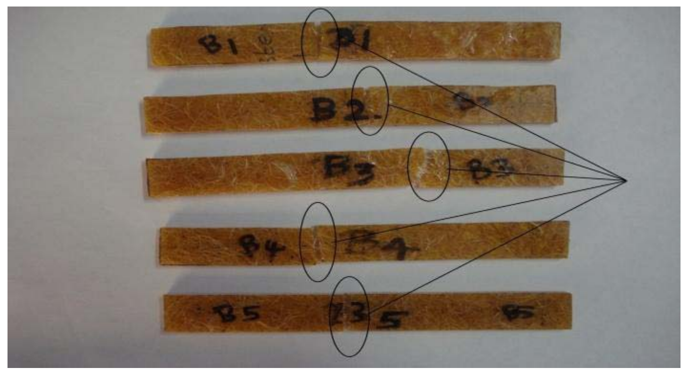

Fig. 6 Photograph of specimens after flexural fracture

Conducted as per ASTM D 256. The test was conducted on the Geeth impact testing machine. The test specimen was supported as a vertical cantilever beam and broken by a single swing of a pendulum. The pendulum strikes the face of the sample and total of five samples were tested and the mean value of the absorbed energy was taken. Figure .7 shows the specimen after impact strength.

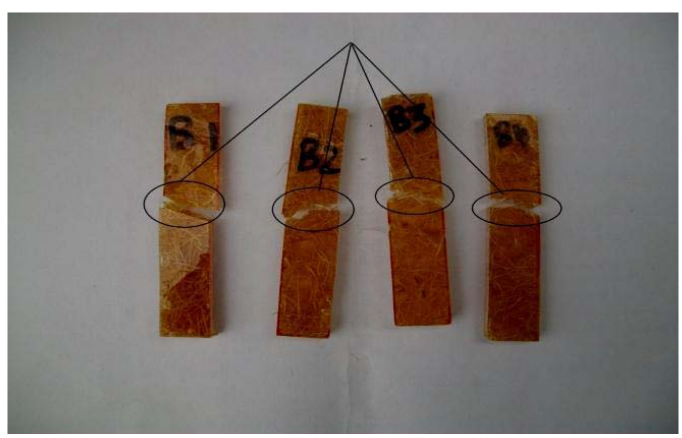

Fig. 7 Photograph of specimens after impact fracture

IV.NONLINEAR REGRESSION ANALYSIS OF MECHANICAL PROPERTIES

The mechanical properties as tensile, flexural and impact strength were modelled using Minitab statistical software. In this mathematical model the terms as F1 represents fiber length and F2represents fiber content in weight percentage. The equations 1, 2, 3are the developed nonlinear regression model of tensile strength (Ts), flexural strength (Fs) and Impact strength (Is) respectively.

$$Ts = 14.011-0.202F1+0.960F2+0.0002F1\ F2+0.001F1^2-0.024\ F2^2 \quad (1)$$

$$Fs = 8.20-0.097F1+2.237F2-0.0005F1F2+0.001F1^2-0.052F2^2 \quad (2)$$

$$Is = -132.367+4.081F1-0.665F2+0.0178F1F2-0.02F1^2+0.056F2^2 \quad (3)$$

V. OPTIMIZATION OF MECHANICAL PROPERTIES

The variables have to be optimized are fiber length and fiber content in weight percentage. The objective function of Maximizing tensile strength, flexural strength, and impact Strength is subjected to the following constraints:
Lower bound= [50 15]
Upper bound= [150 35]
The optimum fiber parameters were found for the Maximum value of one mechanical property or combination of two or all using Minitab statistical package. The optimum fiber length and fiber content for maximum Tensile, flexural, and impact properties are given in Table III

Table III. Optimum fiber parameters

Sl. No.	Fiber Length (mm)	Fiber content (wt %)	Tensile strength (Mpa)	Flexural strength (Mpa)	Impact strength (J/m)
1	50	19	16.17	-	-
2	150	21	-	38.49	-
3	136	29	-	-	164.7
4	150	21	15.56	38.49	-
5	150	27	-	36.58	139.62
6	150	25	15.11	-	130.5
7	150	24	15.35	38.08	123.71

VI. RESULTS AND DISCUSSIONS

A. Effect of alkali treatment

Alkali treatment of cellulose fibers is the common method to produce high quality fibers. Alkali treatment improves the fiber and matrix bonding due to the removal of natural and artificial impurities from the fiber surface. Moreover, alkali treatment reduces fiber diameter due to removal of lignin and thereby increases the aspect ratio. Therefore, the development of a rough surface topography and enhancement in aspect ratio offer better fiber–matrix interfacial bonding and an increase in mechanical properties.

B. Effect of fiber length on mechanical properties

(a) The coir–polyester composite exhibited maximum Tensile strength 0f 16.1709 MPa for the fiber length of 50 mm. The increase of fiber length value above or below this does not affect the tensile properties alone.

(b) The fiber length of 150 mm exhibited maximum flexural and impact behaviour of 38.4912 MPa and 164.73 J/m for the fiber length of 150 and 136 mm, respectively. The higher flexural and impact properties were obtained in long fiber reinforcements.

(c) The maximum value of tensile, flexural, and impact properties of 15.3594 and 38.0881 MPa and 123.715 J/m were obtained for the maximum fiber length of 150 mm only.

C. Effect of fiber content on mechanical properties

(a) The fiber content or fiber loading is playing major role on the mechanical properties of coir–polyester composites. The maximum tensile properties were obtained in the fiber loading of 19%, whereas the flexural and impact properties were obtained in the fiber loading of 29% and 21%, respectively.

(b) All the mechanical properties are maximum in the fiber loading of 24% and the combination of two properties were maximum in the range of 21% to 27%.

(c) The coir–polyester composites exhibited maximum value of tensile, flexural, and impact properties of 16.1709 and 38.4912 MPa and 164.73 J/m for the fiber loading of 19%, 21%, and 29%, respectively.

(d) The coir fiber reinforced polyester composites exhibited higher value of tensile, flexural, and impact properties in the fiber content weight range of 19% to 29%.

VII. COIR COMPOSITES

The low load automobile components can be replaced by coir composites by two reasons namely, low cost and ease of decomposability. The desired colour and good surface finish are obtained by painting the components. The possible applications of coir reinforced composites are

- Light doom, mudguards, name plate, and engine guard in automobiles
- Body panels, frames, bumper, and seat in automobiles
- Welding shield, knife holder, and switch board in general applications
- Switch gear, panels, and insulators in electrical industries
- Musical instruments and children toys

VIII. CONCLUSIONS

The higher value of mechanical properties were obtained in the fiber content in weight percentages between 19 and 30 % .The fiber length was also playing significant role on the mechanical properties. Tensile, flexural, and impact properties of the coir composites were increased due to the improvement of interfacial adhesion between the fiber and matrix. Alkalization treatment of fiber insignificantly enhanced the mechanical properties of the composites. In this study, a maximum value of Tensile Strength 16.1 MPaandFlexuralStrength 38.5 MPa and Impact Strength of 161.9 J/m were achieved for the alkyl treated coir fiber composite and this is more effective than untreated fibers.

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