Study Of Tensile And Flexural Strengths Of Cocoa And Opuntia Fibre Reinforced Hybrid Composites

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Abstract — *In the growing environmental problems, natural fibres seem to be a good alternative since they are abundantly available and there are a number of possibilities to use all the components of fibre-yielding crop; such fibre-yielding plants are Cocoa and Prickly pear (Opuntia). These fibres are characterized by low density, high tenacity and high moisture absorbency in comparison with other fibres. Thus these can be used in manufacturing of hybrid natural composites. In the present work, Cocoa and Opuntia fibre reinforced hybrid composites are produced through hand Lay- up technique. These fibres were treated with 7% NaOH (alkali treatment) and cured for 35 minutes and dried for better fibre matrix adhesion, bending and tensile properties. The objective of the present work is to study the tensile and flexural strengths of four varieties of hybrid composites. The composites include Cocoa fibre-Copper foil composite (F1-Cu-F1-Cu-F1), Opuntia Fibre-Copper Foil Composites (F2-Cu-F2-Cu-F2), Cocoa Fibre-Copper foil-Opuntia fibre composite (F1-Cu-F2-Cu-F1), and Opuntia Fibre-Copper foil-Cocoa fibre composites (F2-Cu-F1-Cu-F2). Each of these composites is having three piles of fibre and two piles of copper foil. They are prepared in 0^0 orientations (fibres in parallel direction), 45^0 (fibres at 45^0 to each other) and 90^0 orientations (fibres in perpendicular direction). The results show that, the tensile strength of F1-Cu-F1-Cu-F1 composite with 0^0 orientation is high (113.60 MPa) and that of F2-Cu-F2-Cu-F2 composite with 90^0 orientation is low (30.53 MPa), and it is also observed from the results that, the bending strength of F1-Cu-F1-Cu-F1 composite with 90^0 orientation is high (31.06 MPa) and that of F2-Cu-F2-Cu-F2 composite with 90^0 orientation is low (26.66 MPa).*

Keywords — *Fibre, hybrid composites, Cocoa, Opuntia, Tensile strength, Bending strength*

I. Introduction

When two or more dissimilar materials are combined, then the resulting material acquires properties superior to its parent materials and is called a composite. The fibre composites because of their better and eco-friendly properties are used in different fields of application such as engineering, sports, defence, aerospace, etc.

Joshi et.al [7] studied the life cycle environmental performance of natural fibre composites and glass fibre composites, concluded that natural composites are superior in specific applications they have studied. Rana et al. [11] experimented on jute fibres and found that the compatibilizer used in jute fibre composites increased their mechanical properties, viz., the flexural strength (as high as 100%), tensile strength (to 120%) and impact strength (to 175%). Shah and Lakkad [14] compared the jute reinforces and glass-reinforces in terms of their mechanical properties and showed that the fibres of jute, when introduced as reinforcement into the resin matrix, improved the mechanical properties considerably. Ray et.al [13] has done alkali treatment to jute fibres at 30^0C with 5% solution of NaOH for 0 hrs, 2 hrs, 4 hrs, 6 hrs and 8 hrs. There was improvement in shear strength for both the fibres and reinforced composites. Saha et.al [8] investigated the physical-chemical properties of jute fibres after treating them with alkali (NaOH) solution. The study was done under three different conditions of alkali treatment, viz., ambient, elevated temperatures, and high pressure steaming conditions. There was an improvement in uni axial tensile strength, flexural strength and flexural modulus.

Hassan et.al [4] reported about the dimensional stability and mechanical properties of the esterified fibre matrix composites prepared by converting the bagasse into a thermo formable material. Ray [12] evaluated the sensitivity of mechanical response under cryogenic (-8^0c temperature) and after thawing conditions by conducting 3-point flexural test on e-glass fibres reinforced epoxy composites at a range of 0.5 mm/min to 500 mm/min crosshead speed. Herrera-Franco and Gonzalez [5] considered the continuous agave fourcroydes (henequen) fibre reinforcement for high density polyethylene and investigated its mechanical behaviour. Rakesh Kumar et.al [9] investigated the characterization of banana fibre and mechanical properties of banana fibre reinforced soy protein composites. Alkali modified banana fibres were characterized in terms of density, denier and crystallinity index. Shibata et.al [15] manufactured bio based polymer composites prepared from kenaf, bamboo and biodegradable resin, studied their young's modulus and flexural modulus, and found that the flexural modulus increased with increasing fibre content. Joseph et.al [6] investigated the effect of fibre length, fibre loading and fibre orientation on the mechanical properties short sisal fibre reinforced polypropylene composites. Alok Kumar Jha et.al [2] studied wear behaviour of the jute fibre and silicon carbide particles (derived from rice husk) when reinforced with epoxy resin. Amico et.al [3] studied the mechanical properties of sisal; glass and sisal/glass hybrid composites stacked in different sequences, and showed that the hybrid composite has got intermediate properties between pure glass and pure sisal. Ramesh et al. [10] studied the tensile strength, flexural strength and impact strength of composites made up of sisal, jute and glass fibre and found that there was an improvement in terms of these mechanical properties. Alavudeen et al. [1] investigated the mechanical properties of composites made up of kenaf fibre, woven banana fibre and banana-kenaf fibres. It was observed that the tensile, flexural and impact strengths of woven banana-kenaf fibre hybrid composites are better than those of their individual fibres.

It is observed from the literature that a lot of research on natural fibre reinforced polymer composites has been carried out, but no work on cocoa and opuntia fibre composites is evidenced so far. This enlightened the scope for the present study which demonstrates the mechanical behaviour of alkali treated and cured cocoa and opuntia fibre reinforced hybrid composites in terms of their tensile and flexural properties.

II. EXPERIMENTAL WORK

The Fabrication and testing of natural fibre reinforced composites includes preparation of composites by hand lay-up technique, cutting of samples of laminates to required dimensions, and testing of tensile and flexural strengths of fabricated natural fibre reinforced composites. The raw materials used in the experimental work are Cocoa bast and Opuntia leaf as the natural fibres, Epoxy resin and hardener, Copper foil.

The cocoa also called as cacao tree is a small tree originally found in tropical South America. Its average height is about 4 to 8 meters. The seeds of it are known as cocoa and are mainly used to produce cocoa butter and chocolate. The cacao trees are nowadays grown in plantations in many tropical countries like India. Fig.1 (a) shows Cocoa tree, the bast of which is used in the present work to draw its fibre. Opuntia belongs to Cactus family which consists of around 460 species. Indian fig Opuntia is one of the common culinary species. Fig.1 (b) shows Opuntia plant, the leaves of which are used in the present work to draw its fibre. Fig.1(c) shows the epoxy resin used in the present work. Epoxy resins are mixed with hardener to improve their strength characteristics. Araldite (HY951) is used as hardener in the present work. Copper metal has excellent properties like corrosion resistance, ductility, fatigue and strength characteristics, which make the alloys of copper the extensively used materials. Thinner foils have lower numbers in strength and fracture strain. Fig.1(d) shows the copper foil used in the preparation of composites.

A. Fibre Preparation

Cocoa stem and Opuntia leaf, after being cleaned and dried, are split into layers by hand slitting. Then their fibres are extracted by removing their outer skin with the help of a knife. Later the fibres are treated with 7% NaOH solution. The NaOH treatment removes the cementing material present in the fibres namely lignin and hemicelluloses, thus increasing the surface area of the fibre. This increased surface area of the fibre leads to better adhesion of the fibre and matrix, thus increasing the tensile strength. Then the fibres are dried. Finally they are cut to desired dimensions and kept aside after being properly weighed. Fig.2 shows the Cocoa fibre and Fig.3 shows the Opuntia fibre used in the preparation of composites.

(a) Cocoa tree

(b) Opuntia leaf

(c) Epoxy resin

(d) Copper foil

Fig.1: Raw materials used in the experimental work

Fig.2: Cocoa fibre

Fig.3: Opuntia fibre

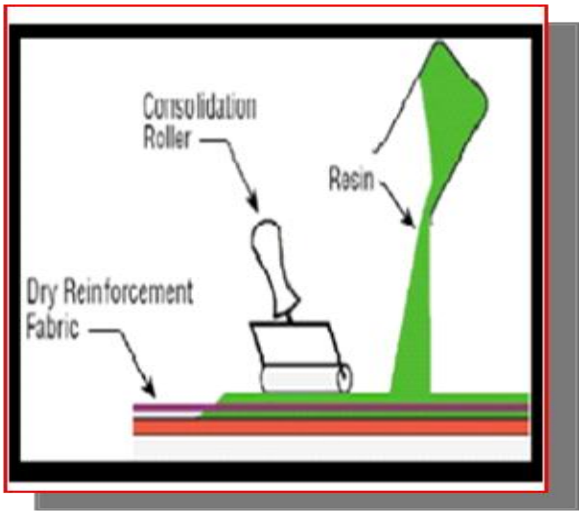

Fig.4: Hand- layup technique

B. Hand lay-up technique for preparing the composites

In the present work, four varieties of hybrid composites in three different configurations (00, 45° and 900 orientations) are prepared by hand lay-up technique. Each of these composites is having three piles of fibre and two piles of copper foil. The 4 varieties of hybrid composites under consideration are F1-Cu-F1-Cu-F1; F2-Cu-F2-Cu-F2; F1-Cu-F2 Cu-F1; and F2-Cu-F1-Cu-F2, where F1 – Fibre of Cocoa, F2 – Fibre of Opuntia, and Cu – Copper foil.

In the process of making the composites, first the fractional weight of each of the composites is fixed as 30% fibre, 55% resin and 15% foil. Then the fibre plies are cut to required size and made ready in quantities of three for each composite. Similarly the copper foil is cut to desired size and two sheets per composite are kept ready for each composite. Later the resin and hardener of required amounts are taken and mixed thoroughly by stirring operation till the mixture becomes little bit warm. The fabrication process starts with placing a thin releasing film on the bottom surface of wooden mould of size 200mm X 30mm X 5mm. Next an accurate amount of polymer coating is applied on the sheet. Then the first ply of fibre of one kind is placed and rolling is done on it. Later a copper foil is placed after a thin layer of resin is applied on the first fibre ply. Rolling is again done by means of mild steel round bar. This process of placing alternative layers of fibres / copper foil in the required sequence with layer of resin between the plies is repeated until five alternating layers have been laid. At last on the final ply a polymer coating is applied to ensure good surface finish to the composite. After proper rolling is done, finally a thin releasing film is placed and light rolling is done again. Then a dead weight of 20 kg is placed on the composite prepared and is left for one complete day so that the composite gets cured and hardened. Fig.4 illustrates the hand lay-up method used in the preparation of composites.

C. Tensile test

Fabricated composites were sheared according to standards in order to perform tensile test for determining the tensile strength and ductility of the composites. The specimen is subjected to a uniaxial tensile load during the experiment conducted on UTM. The dimensions of specimen are 200 mm X 30 mm X 5 mm. Fig.5 shows the UTM with a specimen during tensile test. The failed specimens after performing tensile test are shown in Fig.6.

D. Bending test

The bending or three point flexural test is conducted on the specimens of composites sheared to the required dimensions. Each specimen is prepared to a size of 200mm X 30mm X 5mm. The specimen supported on rollers at its ends is subjected to a transverse central load. Fig. 7 shows the specimen on UTM while it is being tested for bending strength. The failed specimens after performing tensile test are shown in Fig.8.

Fig.5: UTM during tensile test

Fig.6: Specimens after tensile test

Fig.7: UTM during bending test

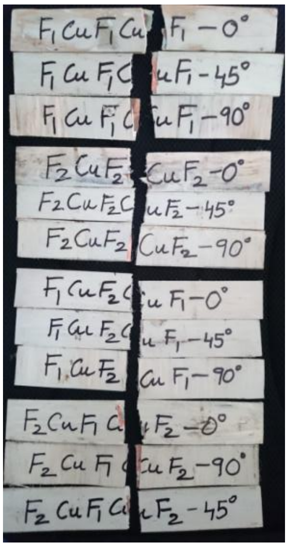

Fig.8: Specimens after bending test

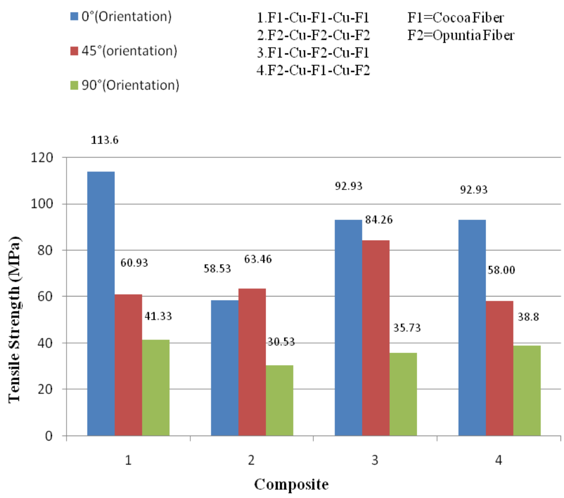

Fig.9: Comparison of tensile strengths of composites with 0^0, 45° and 90^0 orientations

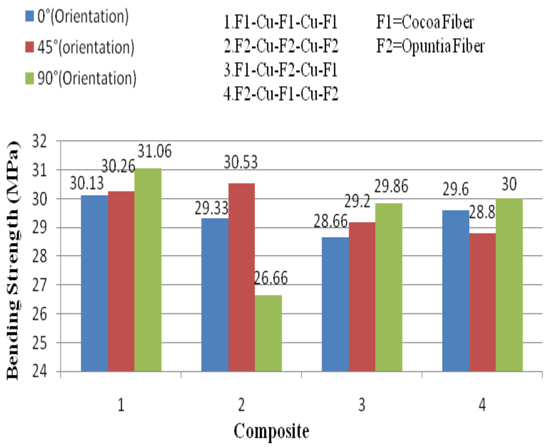

Fig.10: Comparison of bending strengths of composites with 0^0, 45° and 90^0 orientations

III. RESULTS AND DISCUSSION

Table 1 shows the tensile strength, and bending strength obtained out of the tensile and bending tests conducted on the four categories of composites under consideration. Fig.9 shows the comparison of tensile strengths of composites with 0^0, 45^0 and 90^0 orientations. It is observed from the bar chart that, the tensile strength of F1-Cu-F1-Cu-F1 composite with 0^0 orientation is high (113.60 MPa) and that of F2-Cu-F2-Cu-F2 composite with 90^0 orientations is low (30.53 MPa). Fig.10 shows the comparison of bending strengths of composites with 0^0,45^0 and 90^0 orientations. It is observed from the bar chart that, the bending strength of F1-Cu-F1-Cu-F1 composite with 90° orientation is high (31.06 MPa) and F2-Cu-F2-Cu-F2 composite with 90° orientation has the low strength (26.66 MPa).

Table 1: Experimental results of Test Specimens

Composite	Orientation (Degrees)	Yield Strength (MPa)	Tensile Strength (MPa)	Bending Strength (MPa)
F1-Cu-F1-Cu-F1	0	86.00	113.60	30.13
	45	43.20	60.93	30.26
	90	38.13	41.33	31.06
F2-Cu-F2-Cu-F2	0	46.66	58.53	29.33
	45	46.40	63.46	30.53
	90	23.86	30.53	26.66
F1-Cu-F2-Cu-F1	0	34.26	92.93	28.66
	45	35.46	84.26	29.20
	90	34.26	35.73	29.86
F2-Cu-F1-Cu-F2	0	73.46	92.93	29.60
	45	32.53	58.00	28.80
	90	35.06	38.80	30.00

IV. CONCLUSIONS

In the present work, investigation was carried out on the Cocoa and Opuntia fibre reinforced hybrid composites. The investigation includes manufacturing of composites produced through hand lay-up technique and evaluation of tensile and flexural properties according to experimental plan. The major contributions drawn from the investigation are summarized as below:

- The tensile strength of F1-Cu-F1-Cu-F1 composite with 0^0 orientation is high (113.60 MPa) and that of F2-Cu-F2-Cu-F2 composite with 90^0 orientations is low (30.53 MPa).
- Except for the F2-Cu-F2-Cu-F2 composite, the tensile strength of all the composites with 0˚ orientation is high compared to their 45˚ and 90˚ orientations.

- The tensile strength of all the four composites with 90˚ orientation is found to be low compared to their remaining orientations.
- The bending strength of F1-Cu-F1-Cu-F1 composite with 90^0 orientation is high (31.06 MPa) and that of F2-Cu-F2-Cu-F2 composite with 90^0 orientations is low (26.66 MPa).
- Except for the F2-Cu-F2-Cu-F2 composite, the bending strength of all the composites with 90˚ orientation is high compared to their 0˚ and 45˚ orientations.

On an overall perspective, within the purview of the present study, the Cocoa fibre reinforced hybrid composite with Copper as one of the elements in it has obtained better tensile strength than the remaining ones.

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