Mechanical Property Evaluation of Palm/Glass Sandwiched Fiber Reinforced Polymer Composite in Comparison with few natural composites

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Abstract—Natural fibers available plenty can be used as reinforcements in development of eco friendly polymer composites. The less utilized palm leaf stalk fibers sandwiched with artificial glass fibers was researched in this work to have a better reinforcement in preparing a green composite. The commercially available polyester resin blend with coconut shell filler in nano form was used as matrix to sandwich these composites. Naturally available Fibers of palm leaf stalk, coconut leaf stalk, raffia and oil palm were extracted and treated with potassium permanganate solution which enhances the properties. For experimentation four different plates were fabricated using these fibers adopting hand lay-up method. These sandwiched composite plates are further machined to obtain ASTM standards Specimens which are mechanically tested as per standards. Experimental results reveal that the alkali treated palm leaf stalk fiber based polymer composite shows appreciable results than the others. Hence the developed composite can be recommended for fabrication of automotive parts.

Keywords—composites; palm-stalk; nano-filler; fiber-treatment; chopped-fibers;

I. INTRODUCTION

Natural fibers like palm, sisal, bamboo, kenaf, hemp, jute and coir are few bio-degradable natural fibers that are widely used in many automotive applications [1-3]. It is difficult to compromise the properties of natural fibers with synthetic fibers since their properties are closer to metals. Developing a green polymer composite using natural fibers are recent investigations among researchers as these polymer composites possess novel qualities like high tensile strength with less weight, low cost, easily available and holding good fiber matrix adhesion. Natural composites are presently alternatives for synthetic fiber composites [4-5].

Some naturally available fibers presently used as reinforcements in different thermosetting and thermoplastic resins were henequin, sisal, coconut fiber, jute, bamboo, date palm, wood, basalt and banana [6-13]. Many researchers manufactured composites with and without chemical treatment [14-15]. Fillers are added to natural fibers in preparation of composites for high strength [16-17]. Increase in percentage of coconut shell filler content usually increases the tensile strength.

Only inadequate research was done using palm fibers as reinforcement in natural composites. Palm fibers residues plus few percent of coupling agent enhanced the composite characters [18]. NaOH treated palm fruit fiber were analyzed using FEA for tensile properties [19]. The developed Hybrid Oil Palm fibers had good mechanical characters and less water absorption properties [20]. The Sugar Palm Fiber reinforcement showed high tensile and impact strength [21]. Oil palm empty fruit bunch natural fibers with Copper nano-particles revealed biodegradability [22]. Brake pads for automotives are produced with palm kernel fibers [23]. Composite using long palm palm petiole fibers in polyester composites gave good mechanical property [24]. The graphite addition on date palm fibers in epoxy composites gave good mechanical and wear characteristics [25]. The alkali treatment improved the strength of hybrid kenaf/Oil Palm Fruit bunch fibers. Hybrid jute with oil palm fibers reinforced using hand lay-up method finds application in automotive industry [26].

This paper addresses the development of palm leaf stalk fiber sandwiched with glass fiber filled with coconut shell nano filler reinforced polymer composite. Also the results from the treated palm leaf stalk fiber sandwiched with glass fiber filled with coconut shell nano filler reinforced polymer composites are compared with few natural fiber based composites and presented.

II. EXPERIMENTATION

The materials used to develop the sandwiched composites are naturally available fibers extracted from the palm tree in its leaf stalk part as shown in fig.1. To enhance the properties of these fibers 8% KMnO₄ solution was used. Commercially available E-Glass fiber mat was used to sandwich these composite. Coconut shell nano filler was added to fill in the voids formed during polymerization of the composites. To enhance the properties of these fibers 8% KMnO₄ solution was used. Commercially available E-Glass fiber mat was used to sandwich
these composite. Coconut shell nano filler was added to fill in the voids formed during polymerization of the composites. Polyester resin with cobalt naphthanate (hardener), methyl ethyl ketone peroxide (catalyst) forms the base or matrix material in the composites. Wax polish as mould releasing agent was used for mould surface coating.

Fig. 1. Palm leaf stalk fibers extracted from palm tree

2.1 Extraction of fiber and processing
Palm leaf stalk taken from palm tree was soaked in water for two weeks and washed thoroughly to remove the impurities sticking on fibers. The fibers were then thoroughly washed with distilled water to remove further impurities followed by sun drying for about one week. The dried fibers are treated with 8% KMnO₄ solution for about 3 hrs. This enhances the fibers properties suitable for adhesion. Finally the fibers are rolled as mat for reinforcement.

2.2 Preparation of specimen
The Table 1 shows the materials used in various ratio for composite fabrication based on weight percentage. The composite plates A to D are fabricated in this combination. Composite plate A was fabricated with the treated palm leaf stalk fiber mat/sandwiched with E-glass fiber mat/ filled with coconut shell nano filler reinforced into the polyester resin that act as matrix. Composite plate B was fabricated with the treated coconut leaf stalk fiber mat/sandwiched with E-glass fiber mat/ filled with coconut shell nano filler reinforced into the matrix. Composite plate C was fabricated with the treated raffia fiber mat/sandwiched with E-glass fiber mat/ filled with coconut shell nano filler reinforced into the matrix. Composite plate D was fabricated with the treated oil palm fiber mat/sandwiched with E-glass fiber mat/ filled with coconut shell nano filler reinforced into the matrix.

Table 1 MATERIAL COMBINATION IN WEIGHT % FOR FABRICATION

| Specimen | Combinations                                                                 | Weight % |
|----------|-----------------------------------------------------------------------------|----------|
| A        | Polyester resin = 8% KMnO₄ treated palm leaf stalk fiber mat = E-glass fiber mat = Coconut shell nano filler | 70       |
| B        | Polyester resin = 8% KMnO₄ treated coconut leaf stalk fiber mat = E-glass fiber mat = Coconut shell nano filler | 70       |
| C        | Polyester resin = 8% KMnO₄ treated raffia fiber mat = E-glass fiber mat = Coconut shell nano filler | 70       |
| D        | Polyester resin = 8% KMnO₄ treated oil palm fiber mat = E-glass fiber mat = Coconut shell nano filler | 70       |
2.3 Fabrication of Composites for testing:

A mould box of required dimension is used to cast the composites. Hand lay-up method was adopted for fabricating all composite plates. Required amount of polyester resin was mixed with 2% cobalt naphthanate and methyl ethyl ketone peroxide taken in a vessel, 5% coconut shell nano filler was also added and thoroughly mixed. The glass fiber mat was placed as first layer over the molding board and the required amount of polyester resin/coconut shell nano filler mix was poured over it. The trapped air bubbles were removed by gently rolling a hand roller over the fiber mat surface. The successive layers are made with natural fiber mats and the final layer was completed using glass fiber mat. The composites are cured in normal temperature and later removed from the mould box after curing. All the composite plates are sized as per ASTM D standards to performing various tests in order to determine the hardness values, tensile strength, flexural strength and impact strength of all composites.

III. MECHANICAL CHARACTERISATION

3.1 Hardness Value

Rockwell hardness tester was used to compute the hardness values on all the specimens prepared as per ASTM D 785 as shown in the fig 2. Load of 60 Kg applied for 15 seconds on the specimen surface measures the hardness.

![Fig. 2. Specimen for hardness test](image)

3.2. Tensile properties

Tensile properties of 8% KMnO₃ treated natural/ glass fiber mat sandwiched/ coconut shell nano powder reinforced polymer composites are found by testing the samples of each material on a computerized servo controlled UTM machine with specimen standard ASTM D 638 as shown in fig 3. The specimens are mounted in UTM and pulled apart for measuring strength and elongation.

![Fig. 3. Specimen for tensile test](image)

3.3 Flexural Properties

The flexural properties of all samples are measured by conducting Flexural test on computerized UTM using special attachment with specimen standard ASTM D 790 as shown in fig 4. The speed of test was set as 2mm/min at normal temperature.
3.4 Impact Strength

The impact strength of all composites were measured in a charpy impact testing machine. The specimen standards adopted was ASTM D 6110 as shown in the fig 5. The fracture values are the ratio between energy absorbed to sectional area of the specimen.

IV. RESULTS AND DISCUSSION

The composite strength depends on the surface of the fibers and its interface with the matrix. Alkali treatment and addition of nano coconut shell filler material filled the gaps and decreased the voids formed during polymerization providing good fiber matrix adhesion. These characters are detailed as follows.

4.1 Specimen Vs Hardness

The variation of hardness for all the tested specimens was shown in Fig 6. The specimen A recorded maximum value of hardness than the rest.

4.2 Specimen Vs UTS

Fig 7 illustrates the plot of Ultimate Tensile Strength (UTS) in N/mm2 versus specimens combinations, it can be seen that the treated palm leaf stalk fiber/sandwiched glass fiber /filled coconut shell nano filler reinforced polymer composite (specimen A) yielded a maximum of 123 MPa.
4.3 Specimen Vs Flexural strength

The variation of flexural strength for all the tested specimens was shown in Fig 8. The specimen A recorded with increased flexural strength than the other specimens. This shows composite compatibility and fiber interaction with matrix.

4.4 Specimen Vs Impact strength

The variation of impact strength for all the specimens was shown in Fig 9. The specimen A recorded increase in impact strength than the others which results in obtaining the enhanced impact properties.

V. CONCLUSIONS

The fabrication of palm leaf stalk/glass sandwiched polymer composite was successfully completed. The fiber treatment by KMnO₄ soaking improved the mechanical properties like tensile strength, flexural strength, impact strength and hardness value. The various mechanical tests reveal that mechanical properties of alkali treated fibers are superior to those of other compared natural fibers. Alkali soaking significantly removed
surface impurities from fibers so a better fiber matrix adhesion was created. The result reveals that, the trend in all the properties increased for alkali treated and coconut shell nano powder added palm/glass fibers sandwich composites.

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