Abstract

A new variety in natural fibre and is first of its kind i.e. Palmyra Palm botanically called Borassus Flabellifer ‘petiole fibre’ is introduced in the present work. The main aim of the work is to extract the neat fibre and is characterized for its tensile and surface characteristics. The composites are fabricated by reinforcing untreated and treated palmyra palm petiole fibre and are tested for their mechanical, dielectric properties strictly as per ASTM procedures. The highest tensile strength, modulus of 56.69 MPa, 1052.83 MPa is achieved in palmyra palm petiole chemically treated FRP composites. An improvement in the flexural strength, modulus of 3.16 %, 34.76 % is attained for the composites reinforced with chemically treated fibre when compared with palmyra palm petiole FRP composites. The impact strength of 97.07 % more is arrived at the composites reinforced with palmyra palm petiole fibre than the plain specimen. The designer will receive an incitement to select the reasonably light weight insulating material from the data of dielectric strength against fibre content. The surface of untreated and chemically treated fibre is examined using SEM.

1. Introduction

Nature created materials is the natural fibres which are abundantly available, eco-friendly and have renewable in their behavior. The cultivation and on growing harvesting and primary processing conditions to extract the fibre will

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dictate the homogeneity. On one end the natural fibres are light in weight which is extremely advantageous but due to its low density can be disadvantageous in processing since the fibre tends to emerge from the matrix specifically liquid resins. Moisture absorbing tendency is another bottleneck to the natural fibres which resulted in the delamination of the composites. Hence right extraction method of fibre and suitable processing method to manufacture the composites by reinforcing the fibre are the vital foremost tasks in dealing with NFRPC.

Several researchers have put their effort in manufacturing composites using variety of natural fibres (with and without chemical treatment), matrices (thermoplastic, thermosetting plastic etc.) and characterized them for their physical, chemical, mechanical, thermal and electrical properties. Out of that a part of authors have focused on making and characterization of the composites reinforced with short palmyra palm fibrous waste, stem, stem long, palm/jute, palm/banana, borassus fruit fibre in various matrices and the highlights of the same are described below in the order of borassus fruit, short, short hybrid, long, long hybrid palmyra palm fibre reinforced polymer composites.

Sudhakara et al. [1], achieved more tensile strength, modulus, flexural strength, modulus and impact strength for alkali treated/MAPP composites by 4.5, 17, 17.2, 9 and 10 % respectively in case of borassus fruit fibre reinforced polyester composites.

Dabade et al. [2], extracted the palmyra palm fibres from stem and also extracted by chemical means (soaking in 1 % NaOH) solution. They have reported that palmyra fibres up to 50 mm length in the polyester composites have shown increasing trend of flexural strength, and is decreasing thereafter. At 50 mm fibre length, the composites exhibited maximum tensile strength of 42.65 MPa and thereafter it is decreasing.

The mechanical properties of palmyra/banana fibre reinforced composites have shown optimally increased properties at 2 cm fibre length when compared with 3 cm and was noticed by Venkatesha Gowdagiri Prasanna et al. [3]. Fibrous waste formed during separation of palmyra palm leaf, stem base is used by velmurugan et al. [4], to form palm fibrous waste (pfw) reinforced polyester composites. They also prepared pfw/glass FRP composites to compare and contrast the results of the short fibre composites without hybridization. The addition of pfw resulted in improvement in impact strength but they have unable to achieve the tensile, flexural strength with increase in fibre content in the composites.

Thiruchitrambalm et al. [5], studied the effects of chemical treatment on palmyra palm leaf stalk fibre reinforced polyester composites. They have achieved an improvement in tensile strength by 60 % and modulus by 60 % respectively with the reinforcement of mercerized and benzoyl – treated fibre composites respectively whereas permanganate – treated fibre composites shown increase in flexural strength, modulus by 70 % and 110 % respectively, impact strength for mercerized and permanganate treated fibre composites improved by 55 % and 42 % in comparison to the untreated fibre composites respectively. Prasad et al. [6], shown that out of 0°, 45°, 90° orientation of palm fibre reinforced unidirectional composites studied by them, the tensile strength of the composites have 0° fibre orientation exhibited increasing trend with increase in fibre volume fraction.

Palmyra leaf stalk and jute fibres were reinforced into unsaturated polyester matrix and their static and dynamic mechanical properties were investigated by shanmugham et al. [7]. Venkatesha prasanna et al. [8], reported that the mechanical properties were optimally increased at 20 % volume content of alkali treated banana – palmyra fibres when compared with 10 % and 30 % volume content of treated fibres and 10 %, 20 %, 30 % volume contents of untreated fibre reinforced composites. They have also observed that 20 % volume of treated palmyra fibre composites had higher flexural strength than 10 % and 30 % treated fibre composites. The alkali treated fibre composites recored 12 % increase in impact strength at 20 % treated fibre content than untreated fibre composites [9].

Nadendla Srinivasababu et al. [10], introduced Palm Tree Sprout Leaf (PTSL) fibre reinforced polyester composites, The author has characterized the fibre for its tensile properties and morphological study. The composites of untreated and treated PTSL FRP composites are characterized for its mechanical and dielectric properties.

The author has also introduced Palm Fruit Empty Fruit Bunch (EFB) fibre and the one year dried untreated and chemically treated fibre reinforced polyester composites performance is assessed under mechanical and dielectric loadings [11].

So based on the above key points, it is concluded that till today i.e. January, 2014 no one has utilized the petiole fibre in manufacturing of the composites. An attempt is made by the Srinivasababu in the year 2009 itself to introduce a new fibre i.e. palmyra palm petiole and its composites. The objectives of the present work are described under:
• Good extraction of palmyra palm petiole fibre.
• Chemical treatment of fibre.
• Removal of moisture from fibre. Fibre characterization and morphological study.
• Manufacturing and characterization of the composites at various loading conditions.

**Nomenclature**

| Abbreviation | Description |
|--------------|-------------|
| NFRPC | Natural Fibre Reinforced Polymer Composite |
| PPP | Palmyra Palm Petiole |
| PPP – CT | Palmyra Palm Petiole Chemically treated |
| CT | Chemical Treatment |
| FRP | Fibre Reinforced Polyester |
| SEM | Scanning Electron Microscope |

**2. Materials**

2.1. Extraction of fibre

The various sources of fibre in palmyra palm tree are shown in Fig.1a. Out of various indicated fibres, borassus fruit, palm fibrous waste, palm leaf stalk were used by others whereas palmyra palm tree sprout leaf, palm fruit Empty Fruit Bunch fibres are first time introduced by Srinivasababu [10, 11], characterized the fibre and their composites under mechanical and dielectric loadings, the results are published elsewhere.

In the current research work a new natural fibre namely *palmyra palm petiole* is introduced from the palmyra palm tree and the extracted, dried fibre is shown in Fig. 1b. Pure splitting method adopted by Srinivasababu Nadendla and reported elsewhere [10], is employed successfully to extract the palmyra palm petiole fibre.

![Fig. 1. (a) Various sources of fibres in palmyra palm tree; (b) Extracted and dried ‘palmyra palm petiole’ fibre](image-url)
2.2. Matrix

Ecmalon 4413 unsaturated polyester resin supplied by Ecmas resins private Ltd., Hyderabad is used in the present work for fabricating composites for tensile, flexural, impact and dielectric test specimens.

2.3. Chemical treatment

The palmyra palm petiole fibre is soaked in a tub containing the 0.625 M concentration of NaOH for 12 h. Then the treated fibre is washed with huge quantity of water and the fibre is dried at ambient conditions till the moisture is removed from the fibre by natural means. Now onwards this is designated as palmyra palm petiole – CT.

3. Manufacturing and Testing

The composites are manufactured using hand lay-up method according to the procedure described by Srinivasababu Nadendla elsewhere [12]. The tensile, flexural, impact and dielectric test specimens are ground to straight edges using belt type grinder. The fine adhered particulate is removed from all the specimens using fine cloth. The test methods used for fibre, matrix and composites are strictly as per the ASTM procedures followed by the corresponding author and reported elsewhere [10].

4. Results and discussion

An uniformly arranged array of oval shaped dips on the smooth surface of the PPP fibres is visualized from Fig. 2a whereas Fig 2b shows a clear rough and uniformly channeled surface on the fibre after chemical treatment. The density of untreated and chemically treated PPP fibres is determined and the data is given in Table 1.

| Fibre                        | Density (kg/m³) |
|------------------------------|-----------------|
| Palmyra palm petiole         | 727             |
| Palmyra palm petiole – CT    | 1110            |

Fig. 2. (a) Palmyra palm petiole fibre; (b) Chemically treated palmyra palm petiole fibre.

The tensile strength, modulus of 98.14, 156.13 MPa and 1.17, 1.84 GPa respectively is observed for untreated and chemically treated palmyra palm petiole fibres respectively. Fig. 3, 4 represents the tensile strength, modulus
against specimen number, where the chemical treatment of the fibres resulted in increase in the tensile properties for all the specimens and is evidenced from the graphs.

![Graph 1: Tensile strength of palmyra palm petiole fibre](image1)

![Graph 2: Tensile modulus of palmyra palm petiole fibre](image2)

**Fig. 3.** Tensile strength of palmyra palm petiole fibre; **Fig. 4.** Tensile modulus of palmyra palm petiole fibre.

The haphazard trend in tensile strength, modulus exhibited by palmyra palm petiole FRP composite against fibre volume fraction is identified from Fig. 5, 6. This kind of trend is due to the presence of poor bonding between the fibre and matrix, only with the reinforcement level of 12.19 % the composites showed tensile strength of 50.15 MPa which is higher than all other composites reinforced with untreated fibre at different volume fractions i.e. 20.18 – 33.22 %.

At 26.82 % fibre volume fraction the composites exhibited the tensile modulus of 1037.42 MPa. But in overall untreated FRP composites shown varying trend of tensile modulus with increase in fibre volume fraction, which is observed from Fig. 6. The tensile strength of 88.15 %, modulus of 82.87 % more at maximum fibre volume fraction is observed in case of chemically treated palmyra palm petiole FRP composites when compared with bare specimen. An improvement in the tensile strength of 13.04 % is achieved for the composites reinforced with chemically treated palmyra palm petiole fibres at maximum fibre volume fraction when it is compared with the palmyra palm petiole FRP composites at 12.19 % fibre volume fraction.

The tensile modulus of palmyra palm petiole FRP composites is 1037.42 MPa at 26.82 % fibre volume fraction, and has been enhanced to 1052.83 MPa at maximum fibre volume fraction i.e. 22.72 % which is 15.28 % low fibre reinforcement level in the composite than untreated fibre reinforced polyester composites.

![Graph 3: Tensile strength of palmyra palm petiole FRPC](image3)

![Graph 4: Tensile modulus of palmyra palm petiole FRPC](image4)

**Fig. 5.** Tensile strength of palmyra palm petiole FRPC; **Fig. 6.** Tensile modulus of palmyra palm petiole FRPC.
The flexural strength, modulus of palmyra palm petiole FRP composites against fibre volume fraction is graphically shown in Fig. 7, 8 respectively and the composites have shown haphazard trend of flexural properties. This kind of situation is corrected by the composites reinforced with chemically treated fibre, where the increasing trend of the flexural properties is observed.

![Graph showing flexural strength and modulus vs. fibre volume fraction]

The maximum flexural strength, modulus of 62.61 MPa, 8.14 GPa is attained for the composites reinforced with palmyra palm petiole CT fibre at 26.11 % fibre volume fraction. The composites after chemical treatment have shown good adherence between fibre and matrix which is evidenced from the tensile, flexural tested composite specimens. The majority of the fibres are failed due to tension only and some of the untreated fibres are pulled out from the polyester matrix. This may be due to the presence smooth nature of the fibre on part of it’s of outer surface that leads to slip from the matrix by easily breaking the weak interface. The outer most layer of the chemically treated FRP composites are failed due to bending only.

According to ASTM D 6110 – 08 the type of failure observed for all the palmyra palm petiole fibre reinforced polyester composites are designated as ‘H’, which is observed from Fig. 9. The enlarged view of broken portion of the specimens reveals the type of failure and is clearly visible from Fig. 10. The impact strength of the palmyra palm petiole FRP composites is increasing with increase in fibre volume fraction i.e. 0 – 40.94 %. The highest impact strength of 56.73 kJ/m$^2$ is observed for the composites at maximum fibre volume fraction, shown in Fig. 11. The dielectric strength is decreased with increase in fibre content, which is evidenced from Fig. 12. It varies from 9.4333 – 3.7 kV/mm with increase in fibre volume fraction from 12.499 – 29.396 %.
5. Applications

The use of natural fibre reinforced polymer composites is extended to all fields. In the past decades, vegetable fibre composites with thermoplastic and thermoset matrices have been embraced by car manufacturers and suppliers for door panels, seat backs, headliners, package trays, dashboards and interior parts. Some examples of principal car component applications of various vegetable fibres are described below [13].

- Flax, sisal and hemp are processed into door cladding, setback linings and floor panels. Flax fibres are also used in car disc brakes to replace asbestos fibres.
- Coconut fibre is used to make seat bottoms, back cushions, and head restraints.
- Cotton is used to provide sound proofing; it was embedded in phenolic resin and used in the body of the East German Trabant car, the first production car manufactured with natural fibres.
- Abaca is used in underfloor body panels.
- Wood fibres are used in a large number of applications in decks, docks and window frames, and molded panel components.
- Kenaf is used in door inner panels.

Though there are various fibres extracted from various sources are not completely sufficient to satisfy the needs in respective applications. The variability in cross section with in the fibre is relatively more along its length when compared with palmyra palm petiole fibre, which is first of its kind and is introduced in this work only. The properties of the various natural fibres are also reviewed.

From the literature review of nearly 1000 papers, it is evidenced that the palmyra palm petiole fibre and its composites have shown relatively very good results during mechanical loading conditions. Hence the automotive parts made by this fibre may have good mechanical performance and better life span. The more and more analysis and thorough understanding is required to know the behavior of PPP FRP composites behavior in practical, before they may use in various applications. In the present paper the author focused mainly on palmyra palm fibre and their composites, where the fibre was extracted from various sources of the tree to facilitate the clear comparison among various natural fibres extracted from the same tree and to understand their relative performance.

6. Conclusions

Hand lay-up technique is successfully employed in manufacturing PPP FRP composites with relative ease and accuracy. The wastage generated during the extraction of the fibre is 10 %. The soaking time for the present chemical composition yields the very good tensile, flexural properties which are evidenced from the experimental results. The mechanical properties of the palmyra palm petiole FRP composites given enough confidence to fabricate light weight and reasonably good strength parts for automobile door panels, house hold applications like...
doors, window frames etc. But the actual weathering conditions on the composites need to be investigated thoroughly to use them in the respective applications. The dielectric strength data at respective fibre volume fraction gives flexibility to a designer in selecting light weight insulating material.

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