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Study of Fiber Matrix Bonding Property Enhancement in Terms of Flexural Behavior and Macro Analysis of Fracture Behavior of Borassus flabellifer (Palmyra Palm) Fiber Reinforced Polymer Matrix Composites.

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Abstract

Natural fibers have become attractive to researchers as an alternative to synthetic fiber to be used as reinforcing element in terms of strength, modulus and fracture behavior. These include low cost, high specific strength, good mechanical property, non-abrasive, corrosion resistance, biodegradability in comparison to conventional glass, aramid and carbon fibers. Flexural properties are mainly influenced by the interfacial bonding between fiber and matrix. Adopting conventional Hand-lay-up technique, composites were made by aligning untreated fiber, 2%NaOH and 4%NaOH treated fiber into the matrix (polyester resin) and investigated the fracture behavior. There is a gradual increase in the value of the yield strength and modulus ranging from pure composite to untreated fiber, then to 2%treated fiber and then to 4% NaOH treated fiber reinforced composites. These experiments were repeated using 10 multiplication load condition to further investigate the enhancement of flexural strength, modulus and fracture behavior comparing to unloaded condition was observed.

Keywords: palmyra palm, flexural strength, alkali treatment, load condition, fracture behavior.

1. Introduction

A fibre reinforced polymer (FRP) is a composite material consisting of a polymer matrix imbedded with high-strength fibres, such as glass, aramid and carbon, Palmyrapalm [1]. Generally, polymer can be classified into two classes, thermoplastics and thermosettings. Thermoplastic materials currently dominate, as matrices for bio-fibres; the most commonly used thermoplastics for this purpose are polypropylene (PP), polyethylene, and poly vinyl chloride (PVC); while phenolic, epoxy and polyester resins are the most commonly used thermosetting matrices [2]. In the recent decades, natural fibres as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibres [3]. The various advantages of natural fibres over man-made glass and carbon fibres are low cost, low density, comparable specific tensile properties, nonabrasive to the equipments, non-irritation to the skin, reduced energy consumption, less health risk, renewability, recyclability and biodegradability [4]. These composites materials are suitably applicable for aerospace, leisure, construction, sport, packaging and automotive industries, especially for the last mentioned application. However, the certain drawback of natural fibres/polymers composites is the incompatibility between the hydrophilic natural fibres and the hydrophobic thermoplastic matrices. This leads to undesirable properties of the composites. It is therefore necessary to modify the fibre surface by employing chemical modifications to improve the adhesion between fibre and matrix [5].

Another important factor that significantly influences the properties and interfacial characteristics of the composites is the processing parameters used. Therefore, suitable processing techniques and parameters must be carefully selected in order to yield the optimum composite products. There are tremendous research conducted to evaluate performance of natural fiber and it reinforced composite [6-8]. The chemical modification is attempted to improve natural fiber hydrophobic nature, interfacial bonding between matrix and fiber, surface roughness and wettability, and also decrease moisture absorption, leading to the enhancement of mechanical properties of the natural fiber Reinforced composites [9]. Mercerization is a common fiber treatment that extensively used by the number of researcher [10-13].

This article aims to analyse the effects of fiber loading, chemical treatments, manufacturing techniques (hand lay up method) and process parameters on hardness and flexural properties of palmyra palm fiber reinforced polymer matrix composites to justify its bonding strength using extra load (20 kg).

2. Materials and methods

Fiber Collection

Fiber is collected from the stalk of the palm tree. The stalk of the palm leaf is collected. Then these are kept in water for 5 days for the easy separation of the fiber. The palm stalks are taken out from the water and dried in the sun. By this time the stalk gets a bit soft.

The lignin and cellulose components of palmyra palm fiber are separated from the fiber by using hand as neat and clean as possible. Still hundred percent separations is not possible. This was subsequently done by alkali treatment i.e. NaOH treated. The fiber diameter was measured by using stereoscope.

Casting Resin

A polyester resin noted for its clarity and ability to be cast in mass. For the preparation of the composite dried Palmyra Palm fibres are used as reinforcement and polyester resin is used as the matrix material. It is mixed along with the corresponding hardener in a 10:1 ratio by weight intending to make the fibers aligned using two Aluminium frames.

In these Al frames, holes are made by drilling. 30 holes are prepared in each frame. Then the frames are fixed tight in the mold using superglue. Then individual fibers are entered in one hole and taken away from the other hole of another frame. Treated polyester resin is gently poured over the fiber arrangement. It is then post cured in the air for another 24 hours after removing from the mould. The same procedure is to be carried out using 20 kg load on the composite to compare better bonding.

Casting Composite

(1) The die used for pure polyester casting was also used for the casting of composite including the polyester matrix reinforced with fibers untreated, 2% NaOH treated and 4% NaOH treated.
(2) Millot paper was spread on the die surface and was attached with the superglue.
(3) This time also a pair of parallel aluminium frame has been used but unlike the pure casting the frames are drilled into hole by drilling machine. Diameter of the holes is maintained maximum 1mm with distance between the holes being 4mm. All composite castings were prepared by the same frame pairs.The distance between the frames is maintained 130mm.
(4) Now the fibers were introduced through one hole and taken out from another hole of the opposite frame. The alignment of the fibers is maintained throughout the length of the frame.
(5) 3-4 fibers are aligned at a time and the fiber strings were kept in tension using the hand and then the fibers are glued with the edges of the dies. All fibers are aligned in sequence.
(6) When all fibers are set tension then other two sides which were opened were sealed by other two frames. Some tissue papers and lightweight slabs are used to support the frame on the die.
(7) Polyester resin was weighted and taken in a cup.
(8) 2 weight percent of methyl ethyl ketone peroxide (MEKP) which is used as hardener was mixed with the resin.
(9) The mixture was then stirred for 1-1.5 minutes then vacuum treated for 1.5 minutes for the removal of gases and bubbles.
(10) Immediately after vacuum treatment the resin mixture was poured onto the aligned fiber arrangement. Pouring should be done carefully so that all corners of the frames are filled with the resin.
(11) The arrangement is left for 5 minutes for curing. After curing the millot paper is spread over the surface of the casting with due care as to avoid accumulation of bubbles between the casting and millot paper.
(12) To avoid warping lightweight slabs were put on the casting surface and it is kept in this way 8-10 hours. After that desired the composite is obtained.

Alkali Treatment

The chemical coupling method is also one of the important chemical methods, which improve the interfacial adhesion. In this method the fiber surface is treated with a compound that forms a bridge of chemical bonds between fiber and matrix. The chemical composition of coupling agents allows them to react with the fiber surface forming a bridge of chemical bonds between the fiber and matrix. Most researchers found these treatments were effective and showed better interfacial bonding [14].

The Palmyra Palm (Borassus spp)fibres are then prepared for treatment with sodium hydroxide (NaOH) solution to improve its surface properties and provide better adhesion with the matrix after the removal of lignin and pectin from the surface of the fibers. NaOH solution is prepared for two separate concentrations of 2% and 4%. Palmyra Palm samples are first dipped in 2% NaOH solution and 4% NaOH solution. The time for which each stack is dipped in NaOH solutions is 5 minutes. The stacks are then taken out and washed with distilled water for 2/3times. Then they are dried in a heat oven at 70°C for 1 hour each. Drying is done to remove moisture content and to prevent the sticking together and clogging of the fibres with each other. For the preparation of the composite dried Palmyra Palm fibres are used as reinforcement and polyester resin is used as the matrix material. It is mixed along with the corresponding hardener in a 10:1 ratio by weight.

Specimen Preparation for flexural Test

Thicknesses, width of polymer samples are measured, in mm. These dimensions should be approximately the same for each sample. Also make note of any sample defects (e.g. Impurity, air bubbles,etc).

Samples of pure polyester resin and also the composites reinforced with three aligned fibers per sample taken from casting by the assistance of hacksaw and final finishing of the sample was done by grinding. The flexural test is performed in the Universal Testing Machine Instron 1195 as per ASTM D7264.

Fracture Behavior Analysis

Fracture behavior of both pure resin casting and composite casting were analysed in macro level.

3. Results and Discussion

Flexural Comparison

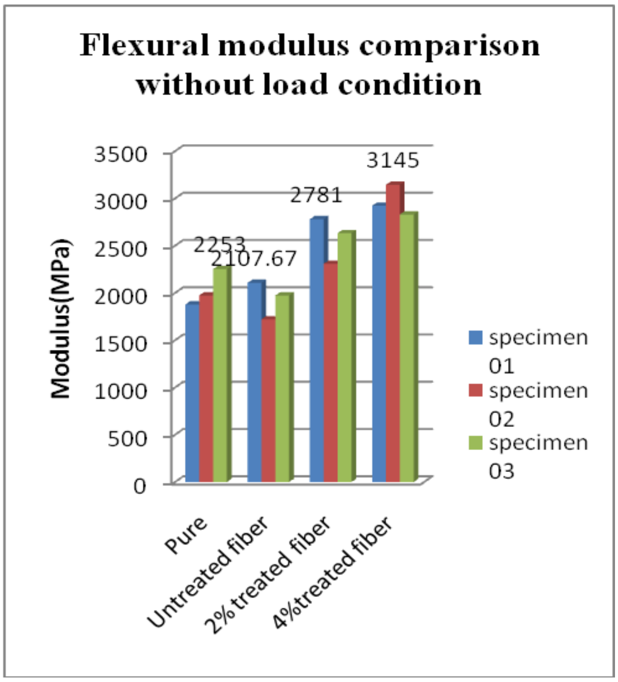

Figure 1: Comparison of Flexural modulus without 20 kg load

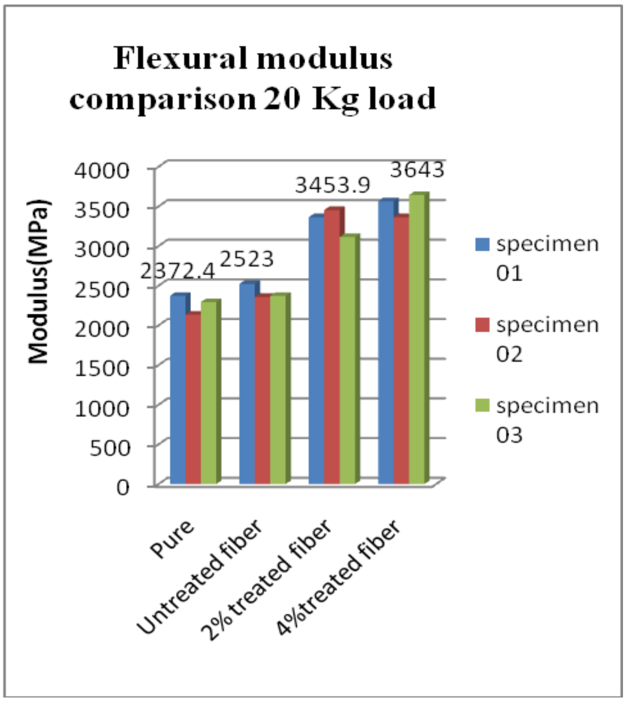

Figure 2: Comparison of flexural modulus with 20 kg load

From figure 1 we see that flexural modulus is optimum for the composite having 4% NaOH treated fiber. We see a gradual increase in the modulus values ranging from the pure casting to the alkali treated ones. From figure 2 we see that the flexural modulus of the composite increases gradually from the pure to the 4% NaOH treated composite. And it is this 4% NaOH treated composite that shows the best result.

Again from both figure 1 and figure 2, we see that with applied load, property of flexural modulus increased compared to unload condition.

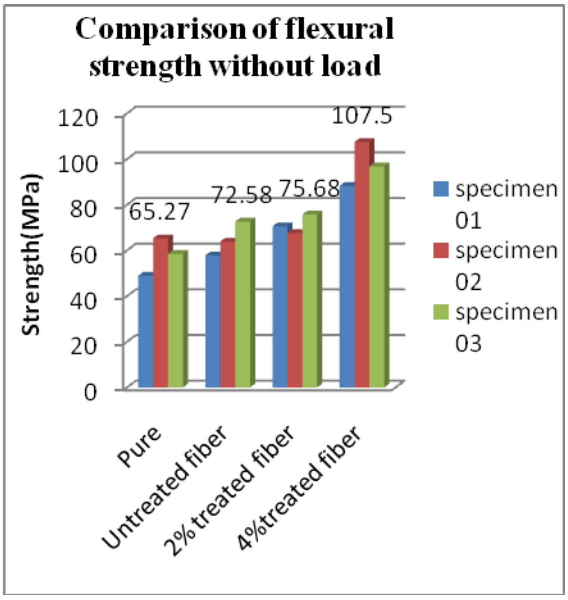

Figure 3: Comparison of flexural strength without load

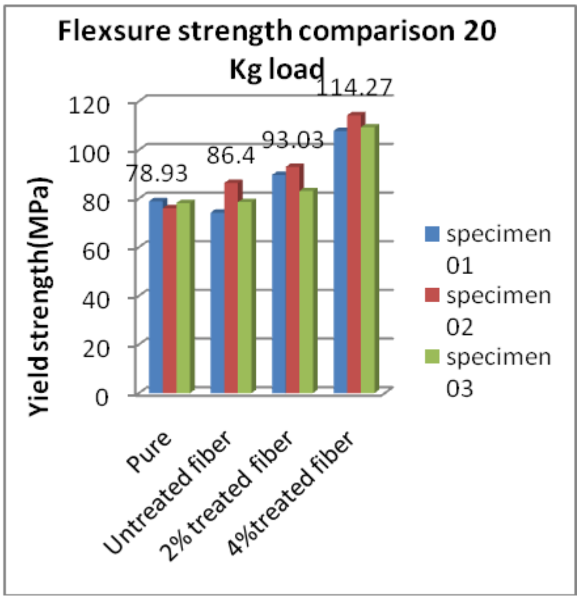

Figure 4: Comparison of flexural strength with 20kg load

Analysing figure 3 and figure 4, we see that there is a gradual increase in the value of the yield strength ranging from pure to 4% NaOH fiber treated castings. Composite with 4% fiber treated shows the best property. Overall best property are shown in loaded condition comparing to unloeaded condition.

Due to alkaline treatment, hemicellulose and lignin are removed, the interfibrillar region is likely to be less dense and less rigid, and that makes the fibrils more able to rearrange themselves along the direction of tensile loading. When fibers are stretched, such arrangements among the fibrils would result in better load sharing and hence in higher stress development in the fiber [15]. When load of 20 kg is applied the overall yield strength is improved. Here again we can see that composite having 4% treated fiber shows the maximum values of the yield strength. In both figure it is seen that the 4% fiber treated composite are having close values of yield strength.

Fracture Behavior

Figure 5: Fracture surface of pure polyester casting

Figure 6: Fracture surface of the composite

Fracture behavior of pure casting and composite shows dissimilarities. In case of pure casting (figure 5) polyester resin casting there a sharp fracture was observed across the cross sectional area. Whereas in case of composite (figure 6) the cross sectional area of the fractured surface shows wavy or ripple like pattern which means the fracture surface is irregular and uneven across the cross section.

In case of pure polyester resin (figure 5) there is no other load bearing element other than the matrix itself. So when the matrix reaches its threshold strength due to the absence of additional load bearing element there is a sharp fracture across the interface.
In case of composite the palmyra palm fiber the composite (figure 6) now has an additional load bearing element. Even if the matrix element exceeds its threshold the reinforcing fiber holds the composite from being broken. This is why the fractured surface of the composite shows wavy or ripple like pattern.
Breaking the fiber due to fibrillation is sited in figure 6, helping to explain the higher strength of composite comparing to pure casting [16].

4. Conclusion

Flexural yield strength gradually increases and it shows highest values for the composite of 4% NaOH treated fiber. Bonding property of the composites of alkali treated fiber also increases. Application of a load of 20 kg increases both the flexural modulus and flexural strength compared to the composites prepared without load. By this enhancement of fiber matrix bonding is observed with the application of 20 kg load. No appreciable change in the hardness values was observed as hardness values was slightly increased on load condition.
Alkali treatment of the raw fiber leads the composite of improved property. Alkali treatment up to a certain point has given optimum properties. Alkali treatment yields better wet ability of fiber surface by the matrix which means an improved bonding will occur. Excessive fiber treatment damages the surface property of the fiber and the fiber matrix bonding becomes weak. Application of additional load further helps in strong bond between fiber and matrix and will improve flexural properties and fracture behavior of the composite.
Therefore, optimum alkali treatment and controlled and uniform loading of the casting product will improve the bonding strength of fiber and matrix which is in conformity with the increased numerical values of the properties.

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