FLEXURAL AND IMPACT CHARACTERIZATION OF UV TREATED ARECA FIBER POLYPROPYLENE COMPOSITES

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Abstract- Polymer based natural fiber reinforced composites are emerging as a promising new engineering material. The main advantage of natural fibers are low density, low cost, biodegradability, acceptable specific properties, availability, less wear during extracting as well as manufacturing composites. This investigation has been carried out to evaluate the interfacial bonding between fiber and polypropylene, flexural and impact properties of composite prepared by areca fibers with randomly distributed fibers. The extracted areca fibers were treated by Ultraviolet radiation to obtain better interfacial bonding between fiber and matrix. The test samples have been prepared as per ASTM standards using injection moulding technique at different fiber weight loading fractions (10%, 20%, 30%, and 40%). Flexural and impact tests have been carried out on the plain polypropylene composites and developed areca fiber-reinforced polypropylene based composites. The treated and untreated areca fiber-reinforced polypropylene composites have been modeled and analyzed by means of finite element method and compared with flexural experimental results. It has been observed that flexural and impact strength increases with increase in the fiber loading percentage when compared to plain polypropylene and untreated areca fiber composites beyond 20% for treated areca fiber composite. The present work also includes the analysis of areca fiber reinforced polypropylene composites using FEA with various fiber volume fractions and these results were validated with the experimental results.

Key words- Areca Fiber, Flexural Strength, Impact Strength, Interface bonding, UV Treatment.

I. INTRODUCTION

In day-to-day activities, the usage of petroleum based products has increased exponentially. Along with this there are numerous unnoticed and undesirable effects that affect the environment are created during product development and disposal, which are ignored. To minimize this, many researches and scientists are working both in research and product application to bring out ecofriendly materials. Natural fiber reinforced polymer based composites are one of the type of eco-friendly material. [1] Recently Natural fiber reinforced composites are emerging as a promising material due to its qualities such as lignocelluloses, light weight, renewable and biodegradability [1] [2]. Studies on most of the natural fibers like cotton, coir, sisal, jute, banana, flex, maize, areca, to list few, have been carried out. Utilization of these fibers has increased due to their diversified and value-added reasons that favour the use of natural fibers instead of any other artificial or synthetic fibers. Natural fibers are lightweight materials having superior strength, competitive specific mechanical properties, high specific modulus, and reduced energy consumption. Further, they are non-toxic & nonhazardous in nature, naturally recyclable, available in abundance, flexible in usage, less expensive and that allow clean energy recovery. To produce composites, these natural fibers can be mixed either with thermosetting or thermoplastic polymer matrix. [1][3][4][5].

To develop these composite materials made from natural fibers with significantly improved strength, stiffness, durability, and reliability, it is important to have better fiber–matrix interfacial bonding. This can be achieved by treating the surface of the fiber. Generally, the surface treatment or modification of natural fibers will not only improve the bonding between the fiber and matrix, but also improve specific aspects such as reducing the moisture absorption sensitivity. Similar polarity between the two materials will enhance the adhesion strength between the matrix and natural fiber. Hence, surface modification / treatment will be a major criterion to improve properties of the fiber. [6] [7] [8] Recent studies have demonstrated that the treated areca fiber with matrix will help in enhancing mechanical properties.

Salma Siddika and Ahmed Sharif [1] have experimented on hybrid fiber combination i.e., Areca and Waste Nylon Fiber with Polypropylene (PP). Results shows that the flexural and impact strength of the composites increases with increase in % of fiber content in composite and later strength decreases with increase in fiber content. C.V. Srinivasa et al. [9, 10, and 11] in their study have considered untreated and KOH treated areca fiber. Formaldehyde and Epoxy Resin with hardener were used to prepare composites, from the results it has been reported that the flexural and impact strength of treated areca fiber with Formaldehyde and epoxy has shown better strength in comparison than untreated.

M. Masudul Hassan et al. [12] have experimented using areca fiber and Jute fiber with PP and M.Ashok Kumar et al. [13] have studied usage of areca fiber and sansevieria cylindrical (Agavaceae) with PP. both have conducted research on hybrid fiber combination and mechanical properties of composites with alkali

treated fibers. From the results, they have shown that both composites with untreated and alkali treated fibers with PP exhibit increasing trend of flexural and impact of the composites with increase in % of fiber content in composite and later strength decreases with increase in fiber content. J. Chakrabarty et al. [14] in their research study have compared the properties of areca fiber composite with alkali treated, detergent wash and untreated with matrix Polypropylene (PP). Similar trend of increasing the strength with % of fiber loading till 30% and later decreases with increase in fiber.

Most of the above-mentioned research work has been carried out using chemical surface treatment of areca fiber which has its own disadvantages [15]. The present research focus on physical surface treatment i.e., Ultraviolet (UV) process to obtain enhanced mechanical properties of areca fibers are reinforced with polypropylene. Untreated and treated areca fiber used as reinforcements in polypropylene polymeric matrix and Injection moulding technique has been used to prepare samples. Short fiber are randomly oriented which provides isotropic properties. So in cases of all directional load application, performances of these composites are quite significant. Enhancement of the interfacial bonding between the untreated and treated areca fiber with polypropylene has been reported. Flexural and Impact properties of the treated and untreated areca fiber reinforced PP matrix have been compared. Finally, the effect of the fiber loading on the mechanical properties and morphology of the areca fiber reinforced PP are also described.

II. EXPERIMENTS

A. Material and Extraction

The thermoplastic polymer polypropylene (PP) used as matrix material, was supplied by the Reliance Company Private Limited in the form of homopolymer pellets. Having melting temperatures of 180o C. Areca raw fruit are taken from a field near Sagar District, Karnataka. Raw fruits were crushed to remove the seed from the shell. These shells were rinsed in running water and soaked for 4 days. This process will loosen the areca fibers from husk and fibers can be easily extracted by hand. Finally fibers were washed again in running water and dried under the sun for about 10 -15 days. The extracted fibers were having the length 40 mm and a diameter of 0.60 mm. These fibers are chopped to 2 to 6mm.

B. Areca Fiber with Ultraviolet Technology for Surface Treatment:

Chopped areca fibers were treated with UV radiation. The UV rays which are emitted from LEDs at 365 nm falls on the areca fiber test sample which is kept at 5.25 cm. Treatment has been carried out with the irradiation of light at forward input current 1 Amp for 1h. Atmospheric temperature and pressure have been maintained during the treatment. [15]

C. Composite Preparation:

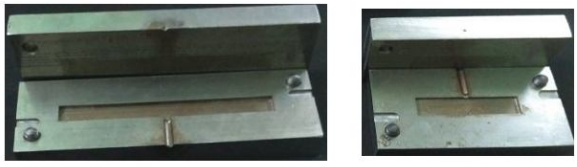
To prepare the composites, dried and chopped areca fiber were mixed thoroughly with PP granules separately by weight % (Wt %) as per the Table-I. Composites were prepared by compounding with help of twin screw extruder machine

Table-I: Polypropylene reinforced with Areca Fiber Composites with relative of amount (%wt)

Fiber As reinforcement (%)	Polypropylene Matrix (%)	Untreated (%)	Treated (%)
0	100	Plain PP	
10	90	UN-10	TR-10
20	80	UN-20	TR-20
30	70	UN-30	TR-30
40	60	UN-40	TR-40

The above-mentioned composition was mixed properly and slowly fed by single screw feeder in to the main extruder machine with help of hopper. The twin screw machine Omega 20P Do/Di 1.80 by M/s. Steer Engineering, Bengaluru, India has been used. The mixture processed at the 500 rpm in co-rotating (both screw in same direction). Material has processed at 185°C at constant pressure. The extruded composite is collected and converted into pellets.

D. Test Sample Preparation:



(a) (b)

Fig.1: Injection mould for (a) Flexural (b) Impact Test Specimens

Test specimens were prepared by adopting Injection molding technique. 3D Modeling and for respective drawing creation of these test specimens were carried out by using Pro-E software. The mold size was considered based on the ASTM specimen standard. Per ASTM-D790-02 standard the composite specimen was prepared for flexural (three-point bending) test and for impact test specimen was as per ASTM- D256-02. Electro Discharge Machining (EDM) and milling process was used to make mould. Fig.1 shows the mould for the test specimen. Injection molding technique has been used to prepare test sample.

After extrusion, the pelletized composites were dried and used in injection molding. Injection moulding was carried out using a hand operated Injection moulding machine. The barrel temp maintained with temperature zones. The Nozzle temperature was 185^{o} C and barrel temperature was 180^{o} C. The mould cooling time was around 1 min and hold pressure was 8 MPa. The mould temperature was around 50^{o} C.

E. Morphology Analysis of Areca Fiber Composites

Morphological analysis of untreated and UV treated areca fiber with polypropylene was carried out by using Scanning Electron Microscope (SEM). Samples were coated with gold using a vacuum sputter coater and analyzed. The morphology changes were observed using Zeiss Merlin FE-SEM a voltage of 5 - 10 kV, and 125 pA probe current.

III. RESULTS AND DISCUSSIONS

A. Determination of flexural and impact properties of the composites:

For the flexural (3-point bending) tests each test specimen was prepared as per the ASTM- D790-02 Standard. The total span of the specimen was supported and loaded at the center of the span through a load cell and the loading rate was 1 mm/min using Mecmesin Universal testing machine. For Izod impact test method, width and depth of each specimen was measured with a micrometer screw gauge and digital caliper. For strength calculation the average dimensions of the test specimens were used. For determining Impact strength the impact energy absorbed by the specimen was determined as per ASTM D256- 02 with notched specimens using Instron Pendulum Tester (9050 Manual Model). All tests were conducted at a standard laboratory atmosphere.

B. Flexural property:

The flexural strength of the plain polypropylene, polypropylene reinforced with untreated areca fibers and polypropylene reinforced with UV treated areca fibers with different fiber loading fraction is shown in Fig.2. From the results, it has been observed that the polypropylene reinforced with untreated and UV treated areca fiber with polypropylene, there is significant decrease in the flexural strength with increase in fiber loading. This is due to the weak interfacial bonding between the fiber and matrix caused by the increase in fiber loading, thus decreasing the flexural strength. There is an increase in flexural strength of about 3.8% with polypropylene reinforced with UV treated areca fibers at 20% loaded composites compared to both plain PP matrix itself. This indicates that at 20% of fiber loading there is significant improvement interfacial bonding between the areca fiber reinforcement and the polypropylene matrix.

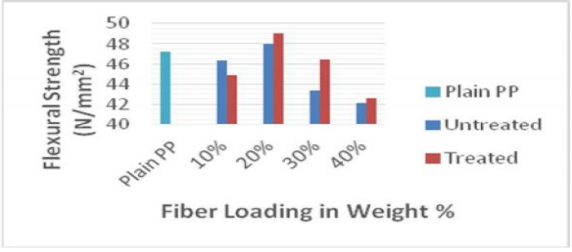


Fig.2: Flexural Strength for Plain Polypropylene, Untreated and Treated Areca Fiber Polypropylene Composite with Different Fiber Loading

C. Impact Strength

Fig.3 shows the Impact strength of areca fiber with PP having UV-treated and untreated areca fibers with different percentage of fiber loading and the plain polypropylene. Izod tests were performed on plain polypropylene, polypropylene reinforced with untreated fibers and plain polypropylene, polypropylene reinforced with UV treated areca fibers and results were noted. The important aspect regarding impact strength of the areca composite is that, UV treated areca fiber composite becomes more brittle than the untreated areca fibers composite.

There is an increase in the impact strength about 29% with polypropylene reinforced with UV treated areca fibers at 20% loaded composites compared to the plain polypropylene. Further, the graph shows that the polypropylene reinforced with UV treated fibers has lesser impact strength than polypropylene reinforced with untreated treated fibers by 18%. The impact strength of composites increases with the weight ratio of fiber with polypropylene initially and then reduces.

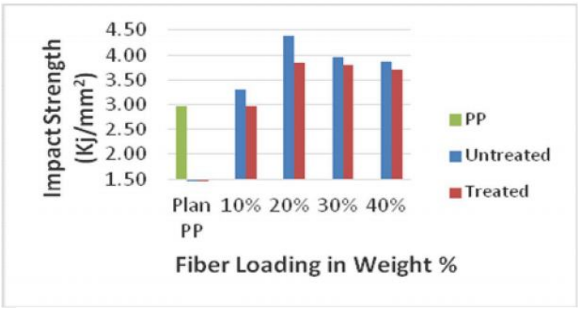


Fig.3: Impact Strength for Plain Polypropylene, Polypropylene reinforced with Untreated and Polypropylene reinforced with Treated Areca Fiber with Different Fiber Loading

D. Finite element Modelling and Analysis:

During the study, ANSYS Workbench software has been used for the finite element technique to analyze the mechanical behavior (structural) of the composite. Flexural analysis has been carried out considering the material modeled based on certain assumptions. The model has been assumed to be an isotropic material with a rectangular section of a beam. The FEA model is constituted of SOLID 95 elements. Fig.4. depicts the flexural stress distribution on the flexural specimen.

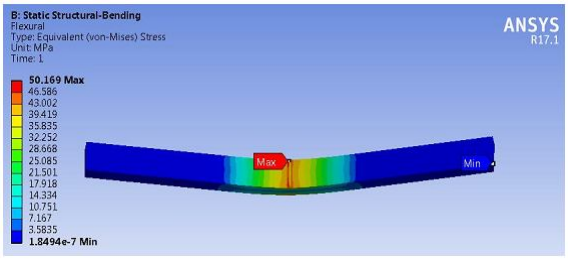


Fig.4: Flexural Stress distribution on the Specimen

Fig.5 shows comparison of flexural strength between the experimental and analysis results of plain polypropylene, polypropylene reinforced with untreated areca fibers and polypropylene reinforced with UV treated areca fiber with different percentage

of fiber loading. Maximum load at failure from the experimental result has been applied for the analysis and a comparison has been made.

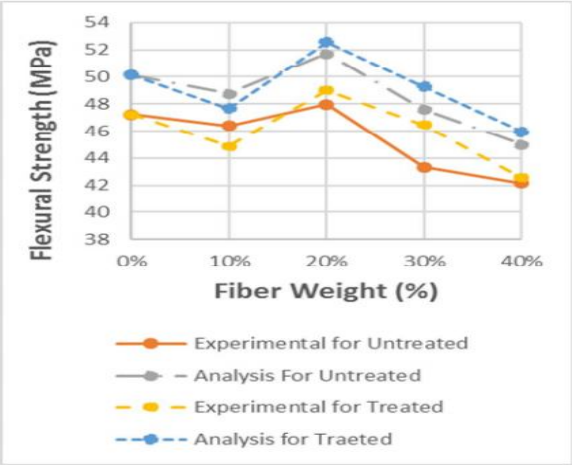
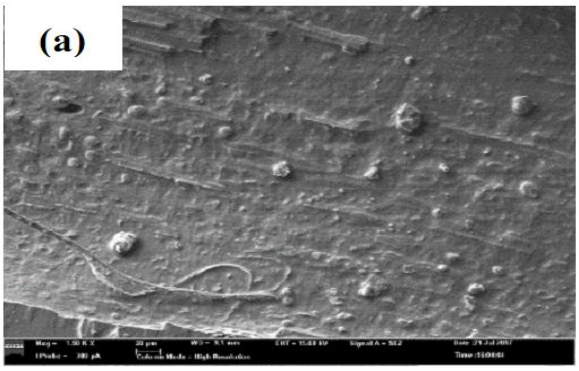


Fig.5: Comparison of Flexural Strength between Experimental and Analysis for Areca fiber PP composite

E. SEM images:

It has been observed that the surface of untreated areca fiber has smoother external surface covered with dense scales, which makes it difficult to get the areca fiber surface wet. Fig.6 (a) shows the untreated (Un) areca fiber surface morphology which has smooth and even surfaces. However, after UV treatment, the surface scales of the fibers have been removed due to the etching effect. During treatment, active ray bombardment will happen on the areca fiber surface which will clean and etch the surface. Thus the treated areca fibers lead to rough surface of the fibers exposing more trichomes which helps in building strong covalent bonds between the fiber-matrix. With this surface, morphological change, it is clearly shown in Fig.6 (b) that wherein it can be seen that the trichomes are strongly bonded with the polypropylene matrix. This indicates very high interfacial bonding in polypropylene reinforced with treated areca fiber. Fig.7 shows the morphological study of the tested samples with interface bonding between the untreated and treated with polypropylene. From the Fig., un treated areca fiber is loosely bonded with polypropylene and while the UV treated areca fiber attached very strongly to polypropylene. This improvement in the interface bonding is because of the rough surface and etching effect due to UV treatment.



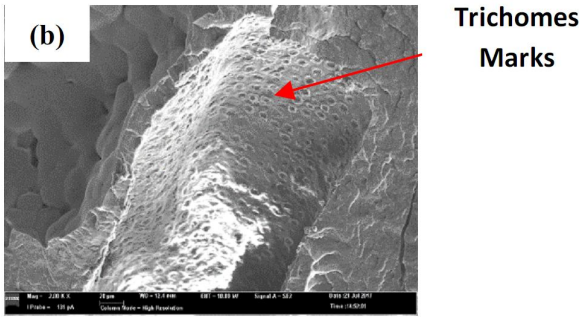


Fig.6: Areca Fibers Trichomes Marks on Polypropylene with (a) Untreated (b) UV treated

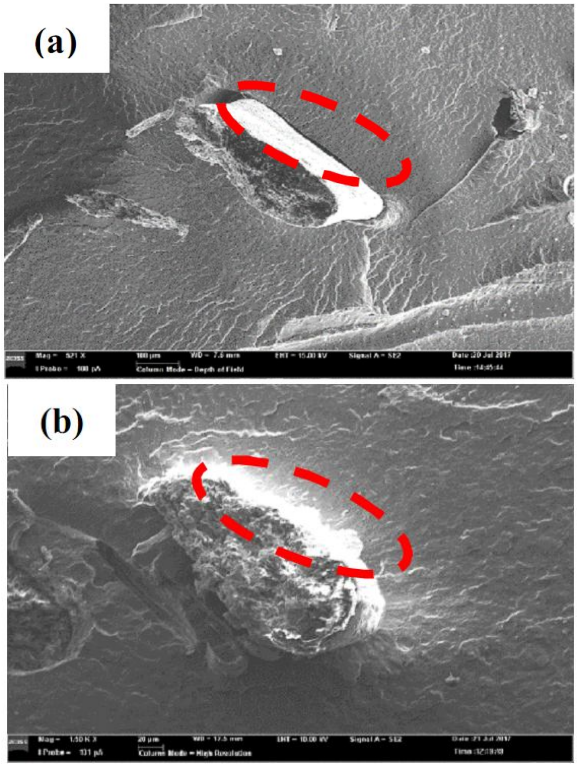


Fig.7: Areca Fiber Bonding with Polypropylene (a) Untreated-Week (b) UV Treated – Strong Interface Bonding

CONCLUSIONS

Polypropylene reinforced with treated Areca fibers and Polypropylene reinforced with untreated Areca fibers composites with various weight fractions have been successfully developed using injection molding technique. Flexural and impact properties were determined experimentally and is validated by the result using Finite Element Analysis. The experimental observation clearly indicate that it is possible to enhance the properties of polypropylene reinforced with areca fiber through UV surface modification of areca fiber. Polypropylene with UV treated fiber surface have, in general, superior mechanical properties when compared to untreated one. From the results, the when compared to plain polypropylene the properties of the polypropylene reinforced with treated areca fibers increased till 20% of the fiber loading, and as the percentage of fiber loading increased the properties display decreasing trend both in flexural an impact strength. Hence

based on the availability of areca fibers, this research gives encouragement to develop advanced composites which are inexpensive and having better strength using UV surface modified areca fiber in polymer matrices for automobile and industrial application.

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