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EFFECT OF PLA COATING ON THE MECHANICAL PROPERTIES OF JUTE-BANANA FIBER REINFORCED HYBRID COMPOSITE STRUCTURES

[1]Ch. Naveen Reddy, [2]Dr. J. Suresh Kumar

[1]Research Scholar, Department of Mechanical Engineering, Jawaharlal Nehru Technological University Hyderabad (JNTUH), Hyderabad - 500085, Telangana. India
[2]Professor, Department of Mechanical Engineering, Jawaharlal Nehru Technological University Hyderabad (JNTUH), Hyderabad - 500085, Telangana. India

Abstract: In the present work, woven jute and banana eco-friendly fibers were used, to increase the adhesion with epoxy and the performance of their composites, woven jute/banana fibres were alkali treated and PLA coated. To study the effect of PLA coating on the mechanical properties like tensile, flexural, impact and water absorption behavior of fabricated jute/banana hybrid composite laminates. The untreated and treated jute/banana fibres were used consisted of alkali treatment and PLA coating to fabricate its polymer-based composites by hand lay-up technique keeping constant fibres content as 30 wt.%. The different hybrid composite laminates untreated (JB1), PLA coated (JB2), NaOH treated (JB3) and PLA coated and NaOH treated (JB4) are fabricated. The percentage of PLA and NaOH treatment used is 5 % respectively. The testing of laminates are carried out as per ASTM standards. The study shows that the percentage increase in tensile strength of PLA coated and NaOH treated specimen (JB4) compared to untreated specimen (JB1) is 20.56%. The NaOH treated and PLA coated hybrid composite structure (JB4) has 16.7% more flexural strength than untreated hybrid composite structure (JB1). Water absorption capacity of PLA coated and NaOH treated Jute/Banana fiber reinforced hybrid composite specimen (JB4) is decreases by 47.6% when compared with untreated hybrid composite specimen (JB1).

***Keywords* – Jute fiber, Banana fiber, PLA coating, Treatment, Hybrid composite**

I. INTRODUCTION

For environmental and economic growth, now a days natural fibres are greatly being used in the various advanced applications like automobile, construction, packaging, house wares, filtration and so on [1], due to their favourable properties such as low cost and density, eco-friendliness, recyclability and biodegradability [2]. Better thermal and acoustic insulation properties were also found in natural fibres as compared to manmade fibres [3]. Moreover, these natural fibres have been considered in place of synthetic fibres owing to advantages such as biodegradability, high toughness, CO2 neutral, and higher specific strength and modulus [4]. Apart from the various advantages of natural fibres, they have some limitations i.e., less moisture resistance, less durability, poor interfacial bonding and poor thermal stability due to which their polymer-based composites are not able to be use in outdoor and high strength applications [5]. In order to overcome these limitations, surface modifications of fibres are carried out to purify and clean the fibre surface by removing great amount of impurities and make them hydrophobic. Chemical treatments such as alkali, silane, potassium permanganate, benzoylation, acetylation, acrylation, isocynate and sodium chlorite of natural fibres have been commonly explored to improve the fibre-matrix interfacial bonding and hydrophobicity through the removal of hydroxyl group thereby improvement in mechanical properties. On the other hand, all these treatments use hazardous chemicals which are harmful to health as well as the environment. Recently, researchers have shown their interest in eco-friendly treatments that are not hazardous and harmful like chemical treatments. In the last few years, sodium hydroxide (NaOH) treatment as eco-friendly treatment has been very popular among researchers. Fiore et al. [6] studied the influence of sodium bicarbonate treatment on the mechanical behaviour of flax/epoxy composite and they found improvement in fibre-matrix bonding thus enhancement in performance of flax composites. M.K.Gupta et al [7] tried to overcome the limitations of jute composites using modified jute fibres by alkali treatment and PLA coating. It was suggested that composite consisting of treated and coated fibres exhibited the best performances in terms of enhancement in mechanical, thermal and water resistance properties. Yadav. A et al [8] evaluated the Effect of chemical treatment sand polymer coating on characteristics of jute fibre. They found that benzyl chloride treated and PLA coated jute composite exhibited the best performance as compared to untreated composite specimen. Sahu.P.et al. [9] investigated the effect of Eco-friendly Treatment and coating on performance of sisal composites. They found that Tensile and flexural performances of treated and coated composites were greater than those of untreated sisal composites, whereas impact strength was found to be reduced. Ratna Prasad et al. [10] evaluated the effect of PLA on Mechanical and Degradation Properties of Natural Fibre Reinforced Composites. They observed that elephant grass fiber reinforced PLA composite as an emerging and stronger composite when compared to jute and sisal/PLA composites. Ismail et al [11] discussed the effect of Void Content on Tensile, Vibration and Acoustic Properties of Kenaf/Bamboo Fibre Reinforced Epoxy Hybrid Composites. They observed that Hybrid kenaf/bamboo composites exhibited less void content, as well as improved tensile, vibration and acoustic properties. Sagar, P et al [13] studied the enhancement of mechanical properties alkali-treatment and polylactic acid coated woven jute fiber reinforced composites. They observed the PLA coated and alkali treated jute composite shown the highest mechanical properties compared with pure jute and alkali treated composites. K. S., Siva et al [12] investigated the effect of fibre length and void content on free vibration and damping behaviour of natural fibre reinforced polyester composite beams. They found that increase in fibre length and void content increases the mechanical and damping properties. By chemical treatments and eco-friendly treatment, the mechanical properties of the bio-composites were enhanced up to some extent. However, a great enhancement in the performances of these composites is expected to be used in advanced applications. Naresh et al [13] studied the enhancement of mechanical properties alkali-treatment and polylactic acid coated woven jute fiber reinforced composites. They observed that PLA coated and alkali treated jute fiber reinforced composites shows that better mechanical properties when compared to untreated and uncoated composites. Enhancement in tensile, flexural and interlaminar properties of jute/polyester composites by silane treatment. In some other studies, silane treatment was found effective to enhance the performances of the composites [3].

Now, it can be concluded that the limitations of the natural fibres were found to be significantly overcome resulting in enhanced properties by the various surface modification methods. Chemical and eco-friendly treatments are found to be useful to improve the properties of the natural fibres and its composites up to some extent. However, a much improvement is needed for advanced applications of the natural fibres and its composites which might be achieved by using polymers coating on treated natural fibres. To the best knowledge of the authors, it can be reported that such type of work as effect of a novel surface modification alkali treatment along with PLA coating on the properties of jute-banana/epoxy composite has not been attempted by any author. Hence, effect of the alkali treatment and PLA coating on the properties of jute-banana/epoxy composite has been presented in present work.

II. MATERIALS AND METHODS

Materials

In this work, the woven Jute and Banana fiber reinforced Epoxy composites are fabricated by using hand layup method. Jute is from Taxaceae blood and its methodical term is corchorus capsularis and extracts from corchorus of the plant, this has less cost fiber. Throughout the world jute produces 2300 $x10^3$ to 2850 $x10^3$ tones. Jute has large choice of applications in industry such as construction, textile and automobile. Jute and Banana fibers were cut according to the dimensions of mold. The matrix material as the Epoxy resin (araldite LY-556) and the corresponding hardener (Araldite HY-951) is provided by the Alide Engineering Services. The properties of matrix material Epoxy are: density =1.16 g/cm3, tensile strength = 85-95 MPa, tensile modulus =35-38 GPa and viscosity = 10000 –12000 MPa s. Woven jute fibres were supplied by Vruksha Composites. The properties of jute fibres are density = 1.3 g/cm3, elongation = 1.7 %, tensile strength = 230 MPa, tensile modulus =27 GPa.

Alkaline treatment on Jute fiber

In the current study, woven jute fibre is treated with 5% NaOH. Jute fibre was submerged in the alkaline solution for 4 hours at 30^0C. After that, the fibre was removed from the solution and repeatedly rinsed with floating water before being immersed in the HCL solution to remove the NaOH adhere from the fiber's exterior [8]. Once more, fibre washed in water and dried for 24 hours in an oven set at 60^0C.

$$\text{Fibre–OH + NaOH} \rightarrow \text{Fibre –O–Na+ + H2O}$$

PLA coating on Jute fiber

Initially, PLA pellets were immerged into the chloroform solution for 8 hours. Subsequently, the solution was stirred manually and heated to 60^0 C to make sure the uniform dispersion of PLA into chloroform solution. After making PLA solvent, woven jute fibres were dipped and then taken out after 5 min soaking time [8]. Finally, coated fibres were dried at room temperature for 24 hours and then finally dried at 60^0 C for 4 hours in a hot air oven. Physical & Mechanical attributes of PLA as shown in table 1.

Table 1: Physical & Mechanical attributes of PLA.

Properties	Values
Tensile strength (MPa)	37
Density (g/cm^3)	1.29
Tensile modulus	27-16
Melting temperature(^{0}C)	173-178
T_g (^{0}C)	55-80
Impact strength (J/m^2)	13

Fabrication of Composite Laminates

The laminates of required dimensions are fabricated with the help of rectangular shape mould made of hardened steel. The dimensions of the mould which is used to prepare the laminates are in the size of 300 mm X 300 mm and thickness 4 mm. In this work hand Lay-up technique is adopted for the preparation of composite laminates because of its flexibility in material design and availability. Layers of jute fiber are marked and cut according to the mould dimensions. Based on the GSM of the fabric the quantity of resin is calculated. The low temperature curing Epoxy resin LY-556 and hardener HY-951 is added to epoxy resin with percentage of 10:1 by weight % and mix thoroughly with the support of vertical stirrer and weight of jute fiber is constant with 40%. The composite laminates made of different composition of untreated, coated, treated and treated & coated were named as JB1, JB2, JB3 and JB4 are shown in Table 2. Finally, the laminates are cut with the help of hack saw in order to get the test specimens as per ASTM standards for characterization and testing. Jute fiber before treatment and after surface modification as shown in figure 1.

Table 2: Nomenclature of composites.

Composites	Jute fiber (wt)%	Alkaline treatment (wt) %	PLA coating (wt) %
JB1	40%	-	-
JB2	40%	-	2%
JB3	40%	5%	-
JB4	40%	5%	2%

Fig 1: a) Jute fiber before treatment b) Jute fiber after surface modification

Tensile test

Tensile test of prepared hybrid composite specimens is carried out as per ASTM D-3039 standard, with a rectangular specimen size 250 x 25 x 4 mm. tensile test is conducted on three different specimens (Untreated, PLA coated, NaoH treated, PLA coated and NaoH treated). During the test, the load was applied to the specimen until it fractures. Tensile strength is derived from stress-strain curve generated.

Flexural Test

UTM (Biss, Nano plug and play Servo hydraulic machine, 100 Ton) was used to perform the tensile test of the fabricated composite's specimens as per ASTM D-638. Flexural test on the specimen (dimension: 165 mm × 20 mm × 3 mm) was performed at a crosshead speed of 1mm/min. The average values with standard deviations of tensile strength and tensile modulus were reported after testing five specimens of each composite.

Impact Test

Digital impact testing machine (Presto Izod/ Charpy Impact testing machine) was used to perform the Izod impact test on the notched specimens as per ASTM D256. Specimens were prepared for this test in dimensions of 65 mm × 13 mm × 3 mm and 2.5 mm notch thickness. The average values with standard deviations of the impact strength and energy were reported after testing five specimens of each composition of the composite.

Water Absorption test

In this work the percentage of water absorbed by the jute/banana fiber reinforced hybrid composite structures are determined by using water absorption test. The water absorption test is done at room temperature with water which is free from salt. For water absorption the test specimens are prepared as per the ASTM D-570 standards. The dimensions of the specimen taken for water absorption test are 30 mm x 30 mm x 4 mm. Before performing the water absorption test original weight of the specimen is calculated.

III. RESULTS AND DISCUSSION

In this work, Jute and Banana fiber reinforced hybrid composite specimens are fabricated using epoxy resin LY-556 and hardener HY-951. Water absorption, tensile strength, flexural strength and impact strength are evaluated.

Analysis of Tensile test

The experimental values of tensile strength obtained from Stress–strain diagram for untreated, PLA coated, NaOH treated, and PLA coated and NaOH treated Jute/Banana fibers reinforced hybrid composites as shown in Fig.2. A positive effect of eco-friendly treatment (i.e. NaOH treatment) and eco-friendly coating (i.e. PLA coating) of Jute/Banana fibers were observed in terms of enhancement in tensile strength of its composite. The tensile strength of untreated Jute/Banana fibre reinforced hybrid composite is found to lower than PLA coated and NaOH treated composites. Composites PLA Coated hybrid composite specimen (JB2), NaOH treated hybrid composite specimens (JB3), PLA coated and NaOH treated hybrid composite specimen (JB4) has 3.06%, 8.23% and 20.56% enhancement in tensile strength as compared to that of composite untreated hybrid composite specimen (JB1). The highest values of tensile properties were offered by NaOH treated and PLA coated Jute/Banana fiber reinforced hybrid composite specimen (JB4), credited to the combined effect of treatment and coating. PLA Coating and NaoH treatment of Jute/Banana fibers helps to advance the hydrophobic behavior of fibers and best possible enhancement in surface roughness thereby a strong interfacial bonding with matrix takes place.

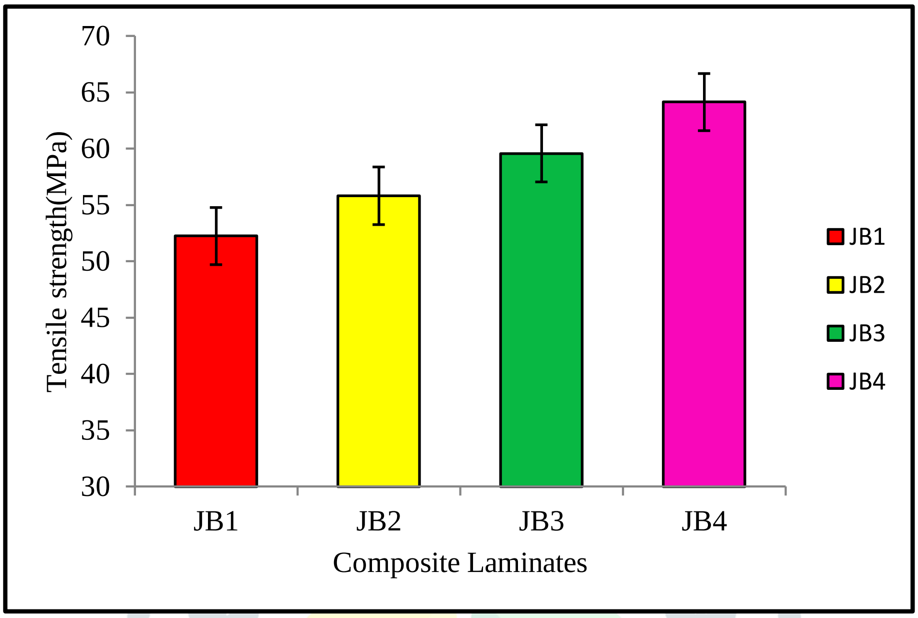


Fig.2: Tensile Strength of Different Composite Laminates

Analysis of Flexural test

From Fig. 3. it is observed that untreated jute/banana fiber reinforced hybrid composite specimen (JB1) has less flexural strength due to poor surface wetting and poor fiber-resin bonding. The percentage increases in flexural strength of PLA coated jute/banana hybrid composite specimen (JB2) is 5.2% more flexural strength than untreated hybrid composite specimen (JB1). The percentage increases in flexural strength of NaOH treated jute/banana fibre reinforced hybrid composite specimen (JB3) is 7.5% more flexural strength than untreated composite specimen (JB1). The highest flexural strength value offered by NaOH treated and PLA coated jute/banana fibre reinforced hybrid composite specimen (JB4). The NaOH treated and PLA coated jute/banana fibre reinforced hybrid composite structures has flexural strength of 88.5 MPa. The NaOH treated and PLA coated hybrid composite structure (JB4) has 16.7% more flexural strength than untreated hybrid composite structure (JB1) due to enhancement in interfacial bonding between fibre and matrix.

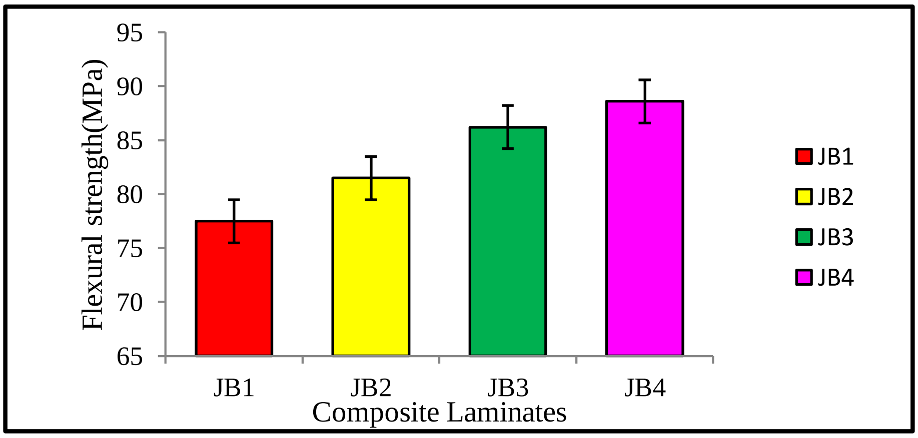


Fig.3: Flexural Strength of Different Composite Laminates

Analysis of Impact test

The impact strength of the composite are mainly depend on interfacial strength, pullout length of fibers. In the impact test, it is observed that the trend of impact test results found the reverse to the results of tensile and flexural test. From Fig. 4. it is noted that the impact energy of PLA coated composite specimen (JB2) is 6 Joules, which is 10.3% less than the untreated composite specimen (JB1) specimen. NaOH treatment provides a strong bonding between fibers and matrix which minimizes fiber pull out and hence decreases in impact strength. The untreated specimen has high impact strength due to larger pullout length of the fiber than the treated one, which has 6.3 joules.

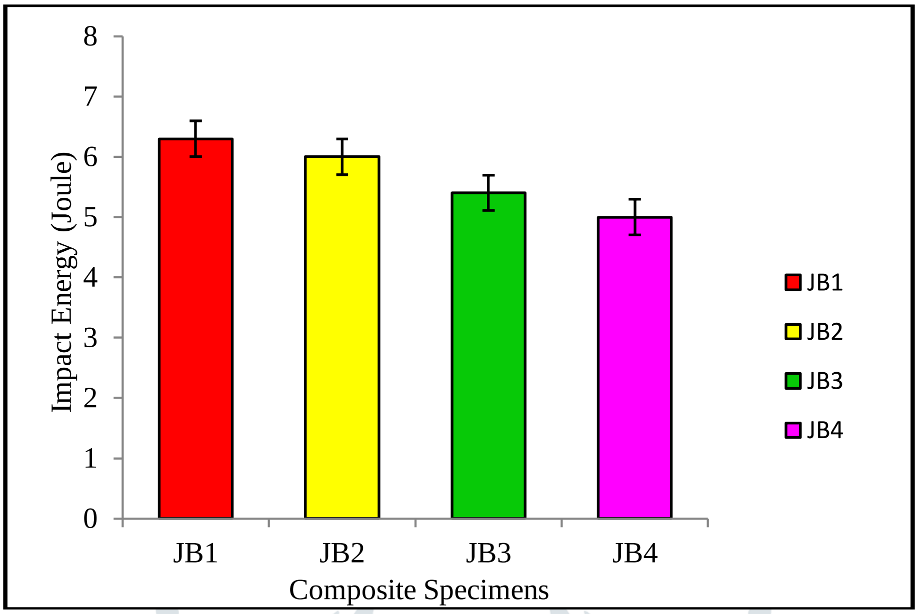
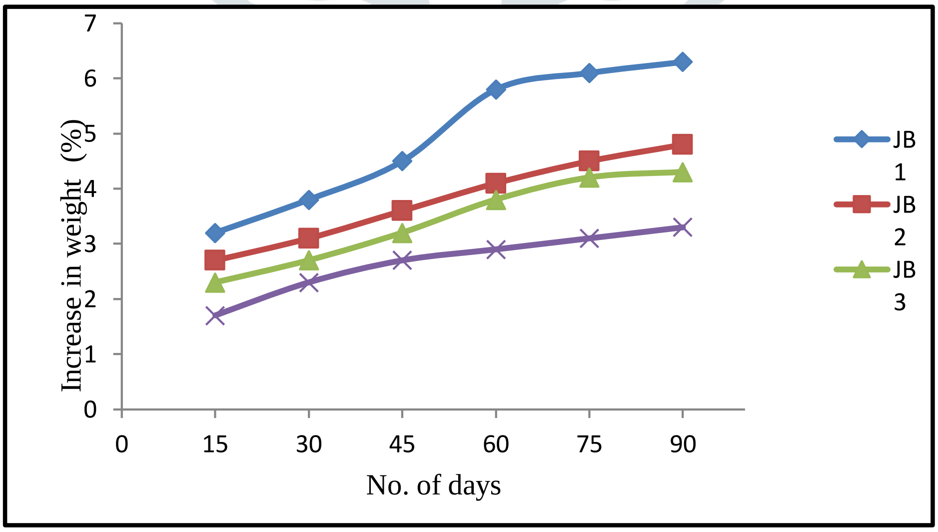


Fig.3: Impact Energy of Different Composite Laminates

Water Absorption Test Analysis

Water absorption capacity of the composite specimens are mainly depending on the different types of fibers and fiber/ matrix interface. The jute fiber absorbs the more water compared to banana fiber. The water absorption test is performed to know the amount of water absorbed by the composite specimens. The increase of water absorption percentage of all composite specimens are noted at specified intervals of time 15,30,45,60,75,90 days. From Fig. 5. it is observed that initially the water absorption rate is more up to 60 days and reaches saturation state and no further water is absorbed. The highest water absorption of the composite specimen (JB1) is due to the hydrophilic nature of the fibers and maximum cellulose content. The lowest water absorption found for the composite specimen (JB4) is 3.3%. The NaOH treatment provides good bonding between the fiber and matrix as it eliminates the lignin and hemicelluloses. The PLA coating acts as protective layer which strongly resist the water absorption.



IV. CONCLUTIONS

The work is carried out to find water absorption and mechanical characteristics of jute/banana fiber reinforced hybrid epoxy composite with NaOH treatment and PLA coating followed by hand layup technique. The mechanical characteristics of prepared jute/banana fiber reinforced composite specimens are analyzed. The specific findings of the present study are:

- The individual characteristics of jute fiber and banana fiber effect the tensile strength of hybrid composite specimens. It is observed that Tensile strength and Flexural strength of PLA coated and NaOH treated Jute/Banana fiber reinforced hybrid composite specimen (JB4) are improved. The impact energy decreases with PLA coating and NaOH treatment.
- The maximum tensile strength and maximum flexural strength are obtained with PLA coating and NaOH treatment.
- Tensile strength and Flexural strength of the PLA coated and NaOH treated Jute/Banana fiber reinforced hybrid specimens (JB4) are improved by 20.56% and 16.77% respectively when compared with untreated hybrid composite structure (JB1).
- The Impact energy and water absorption capacity of PLA coated and NaOH treated Jute/Banana fiber reinforced hybrid composite specimen (JB4) is decreases by 28.57% and 47.6 % respectively when compared with untreated hybrid composite specimen (JB1).

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