EFFECT OF FIBER ORIENTATION ON MECHANICAL PROPERTIES OF NANO FRP COMPOSITES

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Abstract

Fiber Reinforced Polymer (FRP) composites contains strong fibers embedded within a light polymer matrix. Owing to its light weight, high tensile strength, non-corrosive properties, and ease of handling and installation it has gained considerable worldwide interest and growing acceptance in the construction industry. This paper presents the effect of fiber orientation on mechanical properties of nano FRP composites. Here two different combinations of composites FRP are developed with coconut shell powder by layered manufacturing techniques and mechanical properties are measured and compared with different orientation. Observations show that the mechanical property (ultimate tensile strength, impact strength and hardness) yields good result for the 45 degree orientation of hybrid FRP (mixture of polyster, Bamboo and E-glass).

Keywords: orientation: ultimate tensile strength; impact strength; hardness.

I. INTRODUCTION

Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. Natural fibers from plants are beginning to find their way into commercial applications such as automotive industries, household applications, etc. [1]. Natural fibers have received much attention from the research community over the past decade. Natural fibers are now considered as a serious alternative to glass fibers for use in composite materials as reinforcing agents. The advantages of natural fibers over glass fibers are their low cost, low density, high strength-to-weight ratio, resistance to breakage during processing, low energy content and recyclability [2, 3]. Natural fibers have little resistance towards the environmental influences. This can be recognized in the composites and can be advantageously utilized for the development of biological degradable composites with good mechanical properties. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo,and jute to study the effect of these fibers on the mechanical properties of composite materials [4, 5]. Mansur and Aziz [6] studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, flexural, and impact strengths. On the other hand, jute fabric-reinforced polyester composites were tested for the evaluation of mechanical properties and compared with wood composite [7], and it was found that the jute fiber composite has better strengths than wood composites. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer. H.Y.Sastra, et.al [8] discussed the flexural properties of Agenta Pinnata fiber reinforced Epoxy composites. Kazuya et.al [9] studied the tensile properties of bamboo based polymer composites and reported that there was an improvement in the tensile strength and modulus by 15% and 30% than that of matrix. The effect of incorporation of sisal fiber content in high impact polystyrene on stiffness was found to be increasing where as the tensile strength decreases [10]. In literature, many natural fibers like jute, sisal, hemp, coir and banana have been tried and showed their suitability to form a composite [11].Composites having two or more fillers contained in the same matrix are called as hybrid composites [12]. Sreekala et.al [13] reported the effect of hybridization of glass fiber with oil palm fiber reinforced composites. Nikhil Guptha et al. [14] studied the hybridization of fly ash in glass fiber epoxy on compressive and impact properties. Thomas et al. [15] studied the mechanical properties and cure characteristics of sisal and oil palm hybrid composites reinforced natural rubber composites. Banana/Sisal as well as PALF/glass hybrid composites enhanced the tensile and flexural properties (16]. The Mechanical properties of glass/palmyra fiber waste sandwich composites enhance the tensile, flexural and shear strength due to hybridization. Hence, hybridization plays a vital role in improving the properties of composites

[17]. Natural lignocelluloses have an outstanding potential as reinforcement in thermosets. Coconut shell is one of natural lignocellulosic material [18].Coconut shell powder is manufactured from matured coconut shells .Investigations are made to explore the mechanical Behaviour of Coconut Shell Reinforced Polymer Matrix Composite [19]. The behaviour of various fiber reinforced polymer composites are compared with the mechanical properties [20]. A hybrid Fiber Reinforced Polymer composite for bridge girder application for maximum structural performance minimising the production cost[21]. In this work hybrid and nano FRP composites are manufactured and the mechanical properties are tested for the developed FRP's with various fiber orientation.

II. PREPARATION OF TEST MATERIALS

Polyester resin is used as matrix material and bi-directional bamboo fiber in woven form as reinforcing material. Filler materials used in this research are coconut-shell nano powder. Titanium ball mill is used to convert coconut-shell micro powder to coconut-shell nano powder. Preparation of the specimens has been done in the combination of nano powder, polyester resin, woven bamboo fiber and E- glass fiber with different orientation and weight percentage. Specimens C and R were prepared with the combination of 70 Wt% of polyester resin and 15 wt% of bamboo fiber and 15 wt% of glass fiber for both 0°/90° and 45° orientation respectively. Specimens *D* and *S* were prepared with the combination of 70 Wt% polyester resin, 26 Wt% of bamboo and with 4 Wt% of coconut shell nano powder as filler for both 0°/90° and 45° orientation respectively.

Samples of polymer composites were prepared using hand layup method. Moulding box with the required size of $200\,\text{mm} \times 200\,\text{mm} \times 10\,\text{mm}$ was prepared and the surfaces were applied with wax polish which acts as a release agent. Required amount of the polyester resin was mixed with cobalt napthanate which acts as an oxidizer. Measured amount coconut shell powder was added with the resin and stirred well. Methyl ethyl ketone peroxide was used as catalyst. The woven bamboo fiber was placed on the molding board and the prepared resin mixture was applied over the fiber mat, the trapped air bubbles were removed by rollers to avoid void formation. Then additional fiber mat was placed and above steps were continued until the required thickness was attained. These moulded plates were then prepared to specimens as per ASTM D 638-1 standard for tensile test and ASTM D 6110-2

Table 1. Properties of FRP Composite with and without filler for different orientation

Specimen	Combinations	Orientation	UTS (N/mm^2)	Impact Strength (J/mm^2)	Rockwell Hardness Number (H_R)	Flexural Modulus (N/mm^2)
C	70% Polyester 15% Bamboo 15 % E-Glass	0°/90°	87.36	0.83	34.5	2091.51
D	70% Polyester 26% Bamboo 4% nano	0°/90°	46.34	0.22	53	760.51
R	70% Polyester 15% Bamboo 15 % E-Glass	45°	92.26	0.87	34.3	4158.35
S	70% Polyester 26% Bamboo 4 % nano	45°	52.80	0.23	52.5	833.33

standards for Impact test. The orientation is obtained by cutting the specimens in appropriate angle using milling cutter.

Table 1 gives the Properties of FRP Composite with and without Coconut shell micro powder as filler for different orientation.

III. EVALUATION OF MECHANICAL PROPERTIES

Mechanical test such as ultimate tensile test, Impact test, hardness test and flexural are performed on the prepared composites to validate the proposed approach.

A. Tensile Test

In this tensile test the specimens were tested under unidirectional tensile loading until fracture with a computerized Universal Testing Machine. The result of the test helps to optimize the material for different applications. The properties such as final area, yield force, yield elongation, break force, break elongation, tensile strength at yield, tensile strength at break and percentage of elongation are obtained. By using these datas, the properties such as young are modulus, ultimate tensile strength, yield strength etc... were obtained. The prepared specimens as per ASTM D 638-1are tested in Computerized Universal Testing Machine and pulled until failure at a speed of 50 mm/min. Five specimens were tested for each case and the average value is taken for measuring strength and elongation.

B. Impact Test

Charpy Impact test is used commonly to evaluate the relative toughness or impact toughness of material and as such is often used in quality control applications for metals, polymers, ceramics and composites as it is a fast and economical test. The test specimens were prepared as per ASTM D 6110-02 standards. Test is conducted by placing the specimens in horizontal position on the supports against the anvils so that it will be impact on the face against opposite to the notch .A centring Jig is used to position the notch in the centre between the anvils. Raise and secure the pendulum, then zero the excess energy indicating pendulum. Then release the pendulum, allowing the striking edge of the pendulum to impact the specimen. Note the energy absorbed by the pendulum. After all the specimens were tested, calculate the impact strength in J/mm^2 for each individual specimen. Five specimens were tested for each case and the average value is taken.

C. Hardness test

Hardness test is performed on Rockwell Hardness tester to estimate the hardness of the material. Specimens are prepared using ASTM D785 standard. The specimen is placed on the surface of the Rockwell Hardness tester and a minor load is applied until the guage is set to zero. Then a load of 6 N is applied on the middle to the corner of the specimen for 20 seconds and the specimen is allowed to recover for 15 seconds and three sets of readings are taken. Average of the three valves is taken as hardness of the specimen in R scale.

D. Flexural Test

Flexural test (bending test) is done by applying a point load at centre of the prepared specimen. It is carried out using Computerized Universal Testing Machine with a test velocity of 2 mm/min. Specimens were prepared as per ASTM D 790.

IV. RESULTS AND DISCUSSIONS

A. Tensile Property

The specimens were tested in computerized universal testing machine at 2 mm/min at room temperature. Figure 1 indicates the Ultimate Tensile Strength of the specimen (UTS) in N/mm^2 vs. specimens of various combination and orientation. It is found that specimen C Yielded 87.36 N/mm^2 for 30 Wt% of hybrid fiber and 0°/90° orientation, *R* yielded 92.26 N/mm^2 for 30 Wt% of hybrid fiber and 45° orientation. The yield strength increased to about 4.9 N/mm^2 for by varying the fiber orientation to 45°. Specimen *D* yielded 46.34 N/mm^2 for the addition of 4 Wt% of nano powder and reduction of 4 Wt% of pure bamboo fiber for 0°/90° orientation, specimen *S* yielded 52.80 N/mm^2 for the addition of 4 Wt% of nano powder and reduction of 4 Wt% of pure bamboo of fiber for 45° orientation. The specimen S shows a considerable increase of about 6.46 N/mm^2 of UTS by the addition of 4 Wt % of nano powder and 45° orientation. The inclusion of 4 Wt% of nano powder along with 45° fiber orientation plays a vital role in increasing the bonding strength between the fiber and polyester resin inturn increases the Ultimate Tensile Strength. Further increase of nano powder may reduce the Ultimate Tensile Strength as the fiber content gets reduced. Hence the inclusion of nano powder is kept to an optimum level.

B. Impact Property

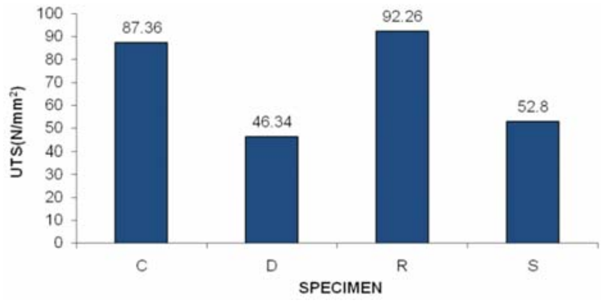

Fig. 1. Ultimate tensile strength

The specimens were tested in charpy impact testing machine at room temperature. Figure 2 indicates the impact Strength of the specimen in J/mm^2 vs. specimens of various combination and orientation. The impact test is done on the specimens *C*, *D*, *R*, and *S* as per ASTM standards. It was observed that the specimen *R* posses an impact strength of 0.87 J/mm^2 due to the reinforcement of hybrid fiber and 45° orientation. The presence of hybrid fiber increases the impact strength due to increased interfacial bond strength between the matrix and reinforcing materials.

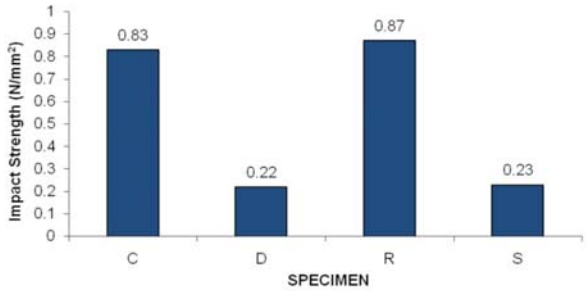

Fig. 2. Impact strength

C. Hardness Property

The specimens were tested by Rockwell hardness tester. Figure 3 indicates the Hardness number of the specimen in HR vs. specimens of various combinations and orientation. The Rockwell hardness number for pure bamboo and hybrid FRP composites with respect to fiber orientation (0/90°, 45°) is shown in Figure 3. Good hardness value is obtained in hybrid fibers than pure bamboo FRP composites. Glass fiber used is in the form of mat and is loosely packed. Hence all parts of the specimen do not exhibit uniform value. The average of the three values was considered. The fibers with 0°/90° and 45° orientation show low impact on hardness value.

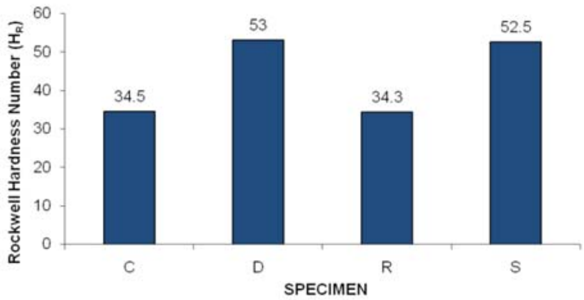

Fig. 3 Hardness number

D. Flexural Property

The specimens were tested in computerized universal testing machine at 2 mm/min at room temperature using special attachments. Figure 4 indicates the flexural modulus of the specimen in N/mm^2 vs. specimens of various combination and orientation. It is found that specimen *C* had a flexural modulus of 2091.51 N/mm^2 for 30 Wt% of hybrid fiber and 0°/90° orientation, *R* exhibit a flexural modulus of 4158.35 N/mm^2 for 30 Wt% of hybrid fiber and 45° orientation. The flexural modulus increased to about 2066.84 N/mm^2 for by varying the fiber orientation to 45°. Specimen *D* showed a flexural modulus of 760.51 N/mm^2 for the addition of 4 Wt% of nano powder and reduction of 4 Wt% of pure bamboo fiber for 0°/90° orientation, specimen S exhibit a flexural modulus 833.33 N/mm^2 for the addition of 4 Wt% of nano powder and reduction of 4 Wt% of pure bamboo of fiber for 45° orientation. The specimen *S* shows a considerable increase of about 72.82 N/mm^2 of flexural modulus by the addition of 4 Wt % of nano powder and 45° orientation. The inclusion of 4 Wt% of nano powder along with 45° fiber orientation plays a vital role in increasing the bonding strength between the fiber and polyester resin intern increases the flexural modulus.

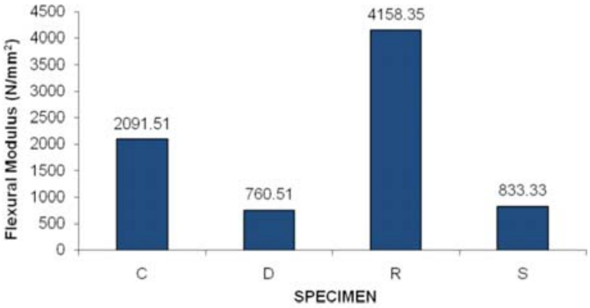

Fig. 4. Flexural modulus

V. CONCLUSIONS

From the research the following conclusions are arrived.

The hybrid specimen with 45° orientation yielded a tensile strength of 92.26 N/mm^2, flexural modulus of 4158.35 N/mm^2 and impact strength of 0.87 J/mm^2 which was higher when compared with others. The only drawback found in using hybrid fiber was that non uniformity of distribution of the fiber in composite.

The above experiments reveal that hybridization of the composites increases the mechanical properties by increasing the bonding strength between the fiber and polyester resin. 45° orientation helps to boost up the mechanical properties of the composites.

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