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Investigation of Bending Behaviour of Polymer Matrix Composite with Jute Fibers as Reinforcement

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Abstract— *The polymer matrix composites with natural fibers have been in use with various industries such as automotive, aerospace, construction and others for different applications. In pursuit to gaining popularity, a natural fiber reinforced polymer composite (NFRPC) with polyester as matrix and jute fabric as a reinforcement along with alumina as particulate material has been synthesized to investigate its mechanical properties. In the present study, the bending behaviour of the composite material has been investigated to know the effectiveness under different load conditions. The study evaluates the effectiveness of natural fiber materials as reinforcement, as they are available in abundant, biodegradable and cost effective. The specimens are prepared using three laminates of size 310 x 310 x 4 mm, produced by hand layup process. Three specific compositions A, B and C with 18%, 22% and 26% by weight of jute fabric along with 8% of alumina and rest of the weight fraction constituted of polyester resin respectively were used to prepare the laminates. The water jet cutting process was employed to cut the specimens as per the ASTM standard dimensions from the laminates. There were 3 specimens for each of the compositions prepared. The specimens were subjected to mechanical characterization tests of tension and compression using Universal Testing Machine (UTM). The specimens exhibited reduced bending strength as the increase in weight percentage of jute fabric and thus denotes good bending strength at 18% and drastic reduction at 24% and 26% of jute fabric reinforcements.*

Keywords— Natural fibers, NFRPC, ASTM, Laminate, Hand Layup, Water Jet Cutting, UTM, Bending strength.

I. INTRODUCTION

Composites are an amalgamation of two or more materials yielding properties superior to those of the individual ingredients. One material is in the form of a particulate or fiber, called the reinforcement or discrete phase. The other is a formable solid, called the matrix or continuous phase. The region where the reinforcement and matrix meet is called the interface. Composite properties are determined by chemical and mechanical interaction of the combined materials

In historical terms the composites have been in use over centuries. Significant examples include the use of reinforcing mud walls in houses with bamboo shoots, glued laminated wood by Egyptians (1500B.C.), Israelites using bricks made of clay and reinforced with straw and laminated metals in forging swords (A.D. 1800). In the 20th century, modern composites were invented in the 1930s with glass fibers as reinforcement with resins. Boats and aircraft were built out of these glass composites known as fiberglass.

NATURAL FIBERS

Natural fibers have been used to reinforce materials for over 3000 years. More currently they have been employed in combination with polymers. Many types of natural fibres have been investigated for use in polymers including flax, hemp, jute, sisal and banana. Natural fibres have the advantage that they are renewable resources and have marketing appeal. These agricultural wastes can be used to prepare fibre reinforced polymer composites for commercial use. Application of composite materials to structures has presented the need for the engineering analysis the present work focuses on the fabrication of polymer matrix composites by using natural fibers like coir, banana and sisal which are abundant nature in desired shape by the help of various structures of patterns and calculating its material characteristics(flexural modulus, flexural rigidity, hardness number,% gain of water) by conducting tests like flexural test, hardness test, water absorption test, impact test, density test, and their results are measured on sections of the material and make use of the natural fibre reinforced polymer composite material for automotive seat shell manufacturing. Present day natural fibers reinforced composites have other commercial applications

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in aerospace interiors, sound / noise control, house interior decorations and others.

II. LITERATURE SURVEY

The literature survey outlines some of the recent reports published in various publications and journals related to Natural Fiber Based Polymer composites. In addition to NFRPC, review also performed on the literature of various natural fibers, their usefulness as a reinforcement material, mechanical and structural properties. PMC materials being used in various industrial, automotive, aerospace and other applications are also being discussed. The review was categorized under the following headings to provide the insight of the study

- Review of natural fibers
- Compositions of PMC
- Mechanical property studies
- Study of Hybrid Composites

Natural fibers in simple definition are fibers that are not synthetic or manmade. They can be sourced from plants or animals. The use of natural fiber from both resources, renewable and non renewable such as oil palm, sisal, flax, and jute to produce composite materials, gained considerable attention in the last decades, so far. The plants, which produce cellulose fibers, can be classified into bast fibers (jute, flax, ramie, hemp, and kenaf), seed fibers (cotton, coir, and kapok), leaf fibers (sisal, pineapple, and abaca), grass and reed fibers (rice, corn, and wheat), and core fibers (hemp, kenaf, and jute) as well as all other kinds (wood and roots). Natural fibers are used in tandem to synthetic fibers such as E-glass and S-glass as they possess relatively low density, large availability, cost effectiveness, ease of manufacturing and processing [1].

Mohanty et al. [3] studied the influence of different surface modifications of jute on the performance of the biocomposites. More than a 40% improvement in the tensile strength occurred as a result of reinforcement with alkali treated jute. Jute fiber content also affected the biocomposite performance and about 30% by weight of jute showed optimum properties of the biocomposites. Modification to the fiber also improves resistance to moisture induced degradation of the interface and the composite properties [6]. In addition, factors like processing conditions/techniques have significant influence on the mechanical properties of fiber reinforced composites [7]. Mechanical properties of natural fibers, especially flax, hemp, jute and sisal, are very good and may compete with glass fiber in specific strength and modulus [8, 9].

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 [10-13]. Schneider and Karmaker [14] developed composites using jute and kenaf fibre and polypropylene resins and they reported that jute fibre provides better mechanical properties than kenaf fibre.

Sudhir.A et al. [15] performed the research activity by preparing hybrid composite material using sisal/jute fibers of 0/40, 10/30, 20/20, 30/10, 40/0 weight fraction ratios while overall fiber weight fraction was fixed as 0.4 weight fraction. The tensile and flexural properties were carried out using hybrid composite samples. The results indicated that addition of sisal fiber in jute/epoxy composites up to 50% weight fraction results increasing the mechanical properties. The best results were observed in 20/20 ratio for tensile strength and bending strength equal to 39.93 and 88.55 MPa respectively.

III. DEVELOPMENT OF EXPERIMENTAL SPECIMEN

The methodology adopted to carry out various requisite preparatory arrangements to prepare PMC specimens are as listed below.

- **Selection of materials**

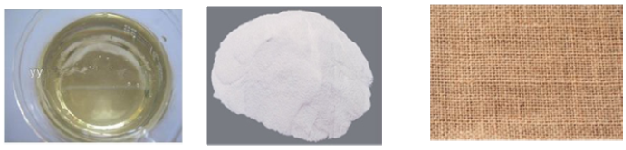

Fig. 1: Materials selected for the composite

- **ASTM standards selection** for the specimen types / preparation

  Bending ASTM D7264 / D7264M

- **Selection of tools / mould** to prepare the specimens

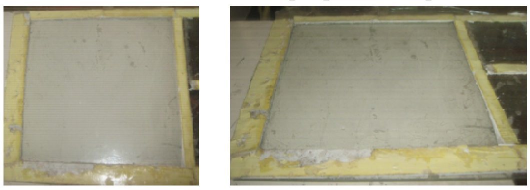

Fig. 2: Surface plate with laminate boundary for laminate preparation

- **Rule of mixture (ROM)** for materials composition

ROM is an important parameter to identify the quantities / composition of the different materials to be added to form the composite.

$$\rho_c = V_m * \rho_m / V_c + V_r * \rho_r / V_c + V_p * \rho_p / V_c$$

Where, ρ_c is density of laminate; ρ_m, ρ_r and ρ_p are density of matrix, reinforcement and particulate materials respectively.

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V_c is volume of laminate: V_m, Vr and V_c are volume fractions of matrix, reinforcement and particulate materials respectively.

- **Materials compositions**

  The material compositions that are formulated for the effective preparation of the composite are as listed in the table below:

Table 1: Material compositions

Sl. No.	Material	Comp. A Wt. %	Comp. B Wt. %	Comp. C Wt. %
1	Polyester Resin	74	70	66
2	Jute Fabric	18	22	26
3	Aluminium Oxide (Al_2O_3)	8	8	8

- **Laminate preparation method-Hand layup Process**

The materials shown in Table 2.1 were used to prepare individual laminate of compositions A, B and C

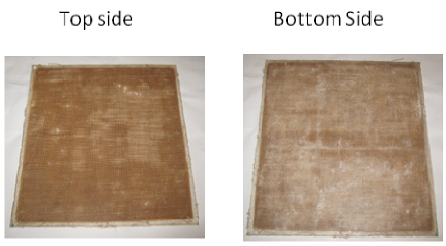

*Fig. 3: Laminate of 310*310*4mm prepared through hand layup process*

- **Water Jet Cutting**

The laminates were cut to the specific dimensions of bending test specimens as per the ASTM standard as noted in the Table 2.2

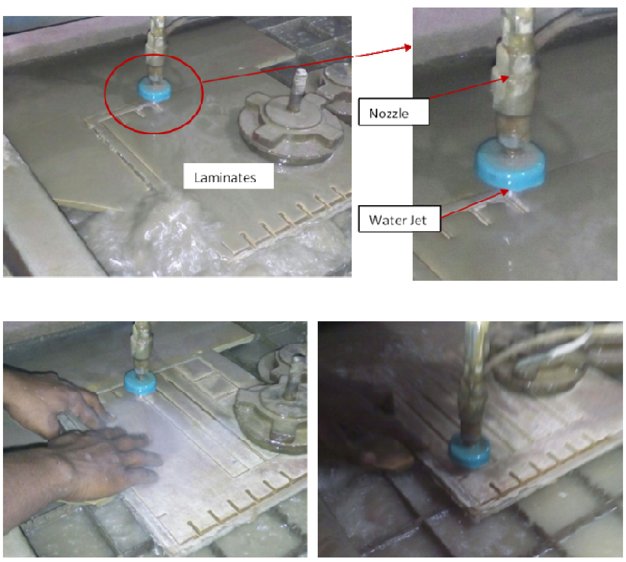

Fig. 4: Water Jet cutting process

Table.2: Bending Specimen dimensions

Sl. No.	Test	ASTM No.	Dimensions (mm)
1	Bending (Flexural)	ASTM D7264 / D7264M	250 x 25 x 4

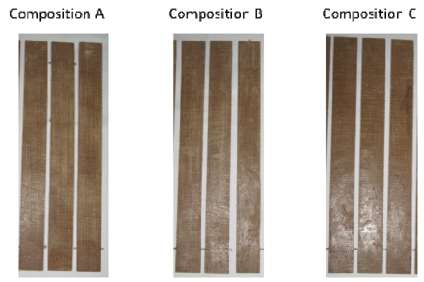

Fig. 5: Bending Test specimens

IV. EXPERIMENTAL METHOD

Bending Test: The test specimens as shown in the Figure 5 were subjected to 3-point bending testing using the UTM. The initial parameters of the test are noted in the acquisition system such as thickness of specimen, support length of the specimen and others. The middle of the specimens is marked as the loading point with the movable arm of the UTM loaded with blunt semi circular vertical member. The specimen is mounted on the support member of the test fixture mounted on the fixed arm member of the UTM. The movable arm with vertical member is taken down with the aid of the controller and made to touch the marking on the specimen with initial load. The specimen is ready to load with the movable arm member loaded on the specimen with controller till its peak load and breaking load carrying capacity. The test results of each specimen are recorded with data acquisition system. The similar test as noted above is conducted for all the specimens with various compositions of A, B and C.

The following Figure 5.6 shows the flexural testing of the specimens that are conducted using the UTM

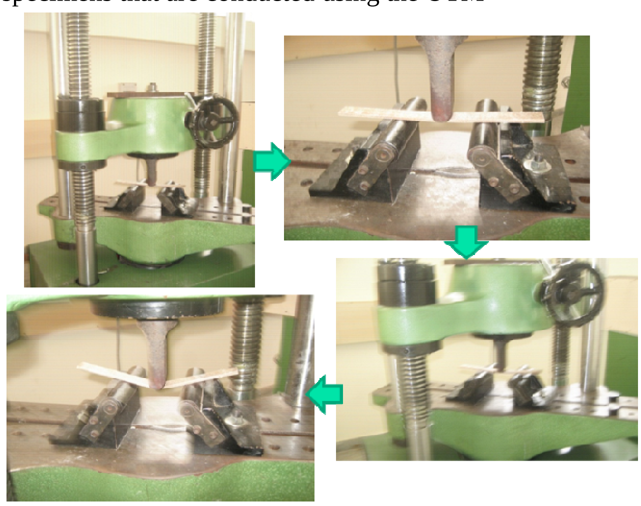

Fig. 6: Bending test of specimens in UTM

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V. RESULTS AND DISCUSSIONS

The values in below Table 3(a) & (b) and the corresponding graphs in Figure 7 (a) to (f) will denote the results for the bending test and the mechanical behaviour of the test specimens that were conducted using UTM.

Table 3(a): Bending Test Results

Sl. No.	Jute Volume Fraction	Peak Load P_{max}	Disp. @ P_{max} (mm)	Breaking Load (MPa/	Max . Disp
1	18	4410	13.73	4340	22.6
2	22	4380	10.76	4230	14.6
3	26	4140	8.43	3920	9.86

Table 3(b): Bending Test Results

Sl.No.	Jute Volume Fraction %	Bending Strength (MPa/ Sq.mm)	Mod. of Elasticity (MPa/ Sq.mm)	Avg. Max Bending Moment (MPa-mm)
1	18	46	5754	503120
2	22	40	7284	564880
3	26	36	8489	573360

The following analyses are noted with respect to the results obtained for the bending test of the PMC specimens.

i. From the test results, it was found that the Peak Load and Breaking Load on the specimens decrease with the increase in weight fraction of the reinforcement material. It was evident from the Table 3(a), for the weight fractions of 18%, 22% and 26% the maximum bending loads were 4410, 4380 and 4140 MPa respectively. Similarly, the breaking loads were 4340, 4230 and 3920 MPa respectively. The decrease in loads is due to increase in wt % of jute fabric which relatively decreases the tensile property at bending and becomes non flexible rigid body which does not take higher loads. The Figure 7 (a) and (c) represents the graphical representation of Peak loads, Breaking Loads with respect to weight fractions of Jute fabric.

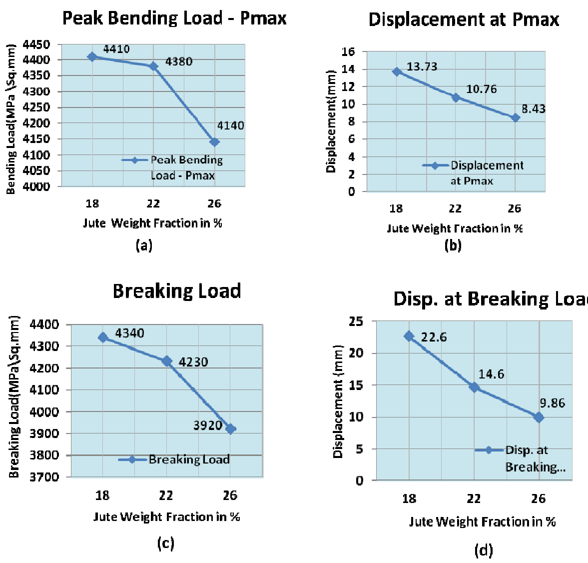
ii. The specimen displacements during Peak load and Breaking Load decreased with the incremental weight fraction of 26%. There was a linear reduction in displacement from 13.73 to 8.43mm at Peak Load and 22.6 to 9.86mm at Breaking Load. This indicates that, at higher weight fractions the material will not sustain more load and will collapse at smaller load. The reason for decrease in displacement is due to the factor that the reinforcement material with matrix reduces the flexible nature and fails the specimens at lower value of displacements. The graphical representations at Figure 7(b) and (d) shows the displacements against the weight fractions during peak loads and breaking loads conditions.

iii. It was known from the result that, there was a decreasing trend of Bending Strength with the increased weight fraction of the reinforcement. Thus, for better bending strength one has to have lesser weight fraction of reinforcement.The decrease in bending strength is owing to the presence of higher wt % of jute fabric which resists the bending and do become brittle due to low wettability of reinforcement with matrix. The chance of presence of voids and kinks formation which reduces the weight bearing property.

iv. Test results show that there was a reduced bending stress with the increase in the weight fraction of the reinforcement material of Jute fabric. Thus it shows that the bending strength will be adequate at lower weight fractions due to its less no. of jute fabric layers.

v. Modulus of Elasticity values have been increased with the incremental value of weight fractions. It was observed from the results that for the weight fractions of 18%, 22% and 26% of Jute fabric the modulus of elasticity values noted were 5573.73, 7283.68 and 8488.52 MPa /Sq.mm respectively. The Figure 7 (e) represents the graph of modulus of elasticity versus weight fractions of Jute fabric.

vi. It is obvious from the results that, due to increased weight fractions there in a definitive increase in bending moment values. This is because of the stiffness of the test specimens in absorbing the bending loads and producing high bending moment at higher weight fractions.



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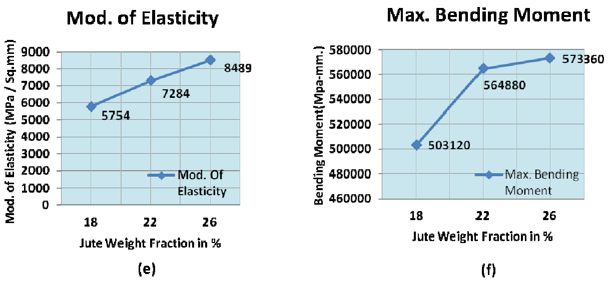

Fig. 7: Bending test Results

VI. CONCLUSIONS

i. The bending specimens displayed a reduction in load carrying capacity with the increased weight fraction of the reinforcement material. Thus the PMC with Jute fabric found to be not supportive for bending type structures. For 18 %, 22% & 26% weight fraction of jute in PMC the ultimate bending load recorded are 4410, 4380 & 4140 MPa/Sq.mm respectively. Also there is a reduction in displacement during ultimate loads at 13.73, 10.76 & 8.43mm respectively.

ii. The bending strength will be adequate at lower weight fractions due to its less no. of jute fabric layers. The results of 46, 40 and 36 MPa/Sq.mm were recorded for 18%, 22% and 26% of jute weight fraction.

iii. It is obvious from the results that, due to increased weight fractions of reinforcement there is a definitive increase in bending moment values. This is because of the stiffness of the test specimens in absorbing the bending loads and producing high bending moment at higher weight fractions.

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