A Study on Mechanical Properties of Symmetrical and Asymmetrical Woven Jute Fiber Composite Polymer

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Abstract: Practice of biodegradable composites increase the attraction due to its lightweight and adequate strength. These plant fiber reinforced composites have captured the attention in construction and automotive industries. Jute fiber is one of the most affordable natural fibers obtained from the genus corchorus plant. In the present article woven jute fiber reinforced polymer composites are analysed to achieve the optimum layers and orientation of fibers for their peak mechanical properties. This study deals with the analysis of symmetrical and asymmetrical woven jute fiber reinforced polymers composite. Different types of composite test coupons are prepared based on number of layers and orientation of fibers like 0°, 15°, 30°, 45°, 60°, 75° & 90°. Polyester resin and Methyl Ethyl Ketone Peroxide is used as a matrix and catalyst respectively. Tensile and flexural strength properties are studied as per respective ASTM norms. The woven jute fiber composites with different orientation exhibits better mechanical properties than randomly oriented fibers. Tensile and flexural tests are conducted and the results are tabulated. It was also found that as the number of layers and orientation angle increases the strength's and modulus of composites are decreased.

Key words: Woven Jute Fiber, Polymer composite, Mechanical properties, Symmetrical, Asymmetrical.

1. Introduction

Focus on the development and eco-friendly consciousness demand of new material with low density, low cost, high-specific strength, non-toxicity, and biodegradability is increased. These can be achieved by use of natural fiber reinforced composites. These natural fibers are strong, lightweight, and free from severe health hazards, recyclable and hence they have the potential to be used as building materials [1]. Jute fibers are most commonly used as a reinforcing material in polymer composite. They are low cost and have high tensile strength, high chemical resistance, and high dimensional stability [2].The mechanical properties of composite materials depend on many factors, which include fiber length; shape and size of fibers, composition, orientation and distribution, as well as volume fraction, mechanical properties of the polymer matrix, manufacturing techniques and adhesion or connection between the fibers and the matrix [3]. Sanjay and Yogesha showed that mechanical property of jute fiber/polymer composite has been investigated and is noted that, here we observe increment in tensile and flexure property when woven jute fibers is used as reinforcement [4]. The properties of the natural fiber reinforced polymer composites can be improved by using woven jute fiber. The concept of using woven jute fiber in layer with different orientation gives encouragement to the users according to the requirements, which is one of the major advantages of the composites. The utilization of bi-directional fibers rather than of distributed short fibres has the extra benefit of diminishing the fibre agglomeration and obtaining the same properties of composites in both directions. It is generally observed that when the fiber loading is increased, it results in increment of tensile properties. The arrangement of layers has adverse effect on the flexural and inter-laminar shear properties when compared to tensile properties which thus reduce the mechanical attributes of composites [5].Naidu et al have reported that even though the mechanical property of woven jute/polyester composite does not provide high strength and moduli as that of random distributed composites, these provide good strength than of wood composite and some plastics. Hence, these composites can be utilized for future purpose [6]. Verpoest et al commented on jute fiber epoxy matrix composites which were casted with the vacuum assisted resin infiltration (VARI) method. Stacking arrangement were (0/0/0/0), (0/+45°/-45°/0) and (0/90°/90°/0). In every case, the total volume fraction of jute fiber was 25%. The obtained composite were classified by its tensile test and the results which were got compared with the theoretical ones. In the stacking sequence of 0/0/0/0 and 0/+45°/-45°/0, tensile strength in longitudinal direction was observed and the highest as that of in the transverse direction when compared. In the case of, 0/90°/90°/0 laminate composite, tensile strength in warp and weft direction was almost equal to one another [7]. The market scenario for composite applications is changing due to the introduction of newer biodegradable polymers. Composite materials reinforced with natural fibers, such as flax, hemp, kenaf and jute are gaining importance in automotive, aerospace, packaging and other industrial applications [8].

2. Materials and Experimental details

2.1 Materials

The basic raw materials utilized to prepare the experimental composites are Woven Jute fibers (in the form of woven fabric mat) are used as a reinforcing material and it is made of Jute fiber. The thickness of jute mat is about 0.7mm-0.8mm and density of jute fiber is about 1.13gm/cm3. Polyester resin is thermosetting polymer used as matrix material which is having density of 1.10 g/cc and having high viscosity. Solution of Methyl ethyl ketone peroxide (MEKP) which acts like a catalyst and it is it helps in speed up the curing of compound. MEKP will help in hardening of composites in short interval of time. Cobalt naphthenate is a transparent fluid with low viscosity compare with polyester resin which acts like a hardener. It goes about as curing specialist and it will speed up the chemical reaction.

2.2. Specimen preparation

Eight kinds of specimen are prepared based on number of layers and orientation of woven jute fibers. The woven Jute mats are cut into a size of 30 cm X30 cm with different angles like 15°, 30°, 45°, 60°, and 75° based on requirement and stacked one above the other to form different combinations of laminates the jute mats are stacked with various combinations of angles and also 5 symmetrical and 3 asymmetrical combination is done. The dimension of jute mat is 30cmx30cm.Polyester resin is thermosetting polymer that polymerizes and cross connections when blended with Cobalt naphthenate and MEKP. To set up the matrix, polyester resin is weighed and taken in container. Hardener and catalyst are mix at the proportion of 100:1:1, then altogether stir for a minute for uniform blending of matrix. The jute mats kept in order is not disturbed. The resin is mixed uniformly in the form of layer by layer using Hand Lay-up technique. Compress the Mould by hand tightening and maintain the standard pressure with the temperature of 80-85˚C. Temperature should be maintained due to better wet ability of jute fiber with polyester matrix. Also have to maintain the pressure due to removal of voids and uniform thickness. After set the temperature at 80-85 ˚C keep the mould in hot compression machine for 20 minutes for curing. After 20 minutes remove the composite from the hot compression machine. The jute polyester matrix was manufactured for different stacking sequence. Totally 8 different laminates are fabricated with 3 different orientation angle & 5 different symmetrical sequence. These composites specimens were made according to standards of ASTM D3039 and ASTM D7264 for the testing of tensile and flexural properties. The specimens subjected to tensile test were of size 250 mm x 25 mm. The thickness of test specimens varied from 2 mm to 6 mm respectively. All the tension tests were conducted on a computer controlled Universal Testing Machine (UTM) of 50kN capacity with a strain velocity of 3mm/minute and the results were recorded.

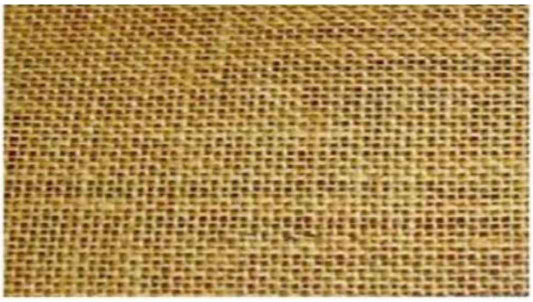

Figure 1: woven Jute fiber

Table 1: Fiber volume fraction of woven Jute fiber polyester Composite

Symbol	Stacking Sequence	Number of ply	Thickness in mm	Weight of Fiber (gm)	Weight of resin (gm)	Volume Fraction of Fiber (%)	Volume Fraction of Matrix (%)
JS1	0/15/30/45/60/75	6	5.51	198	292	37.3	62.7
JS2	0/30/60	3	3.35	100	195	31.02	68.98
JS4	0/15/45/75	4	4.36	132	283	29.03	70.97
JS5	0/30/45/45/30/0	6	4.62	140	210	36.89	63.11
JS6	0/15/30/30/15/0	6	4.85	140	235	34.32	65.68
JS7	0/45/45/0	4	4.04	92	188	30.03	69.97
JS9	0/15/45/75/75/45/15/0	8	5.84	184	286	36.07	63.93
JS10	15/30/45/60/75/75/60/45 /30/15	10	6.61	230	305	39.81	60.19

3. Results and Discussion

3.1 Tensile Properties

Tensile properties of composites depend on adhesion of polyester and fibre mats. This tensile testing is performed in computerized governed universal testing machine (UTM) of 5 tons capacity. A uniaxial load is applied through one end. The tensile samples were made by ASTM D 3039 standards. The samples were of size 150 mm long, 25 mm wide for every thickness. The samples were tested in computerized UTM with a strain velocity of 3mm/minute. For peak value tensile property of sample is obtained. Tensile behaviour of the untreated jute polyester composites is results were obtained in Table 2.

The tensile strength is calculated from the formula.

$$\text{Tensile strength} = \frac{\text{Maximum Load carried}}{\text{Bredth X Thickness}}$$

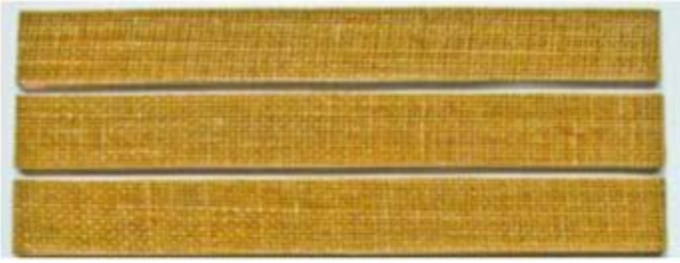

Figure 2: Tensile Specimen

Table 2: Tensile strength and Modulus of woven Jute fiber polyester Composite

Symbol	Stacking Sequence	Number of ply	Thickness in (mm)	Ultimate Load (N)	Elong ation (%)	Tensile Strength (MPa)	Tensile modulus (MPa)
JS1	0/15/30/45/60/75	6	5.51	3022	4.57	21.92	475.79
JS2	0/30/60	3	3.35	1076	2.82	12.85	428.26
JS4	0/15/45/75	4	4.36	2554	2.99	23.43	775.87
JS5	0/30/45/45/30/0	6	4.62	1582	3.63	13.69	357.24
JS6	0/15/30/30/15/0	6	4.85	1604	4.43	13.23	295.29
JS7	0/45/45/0	4	4.04	1284	4.36	12.71	290.25
JS9	0/15/45/75/75/45/15/0	8	5.84	1522	5.24	10.42	175.3
JS10	15/30/45/60/75/75/60/ 45/30/15	10	6.61	748	33.63	4.71	12.33

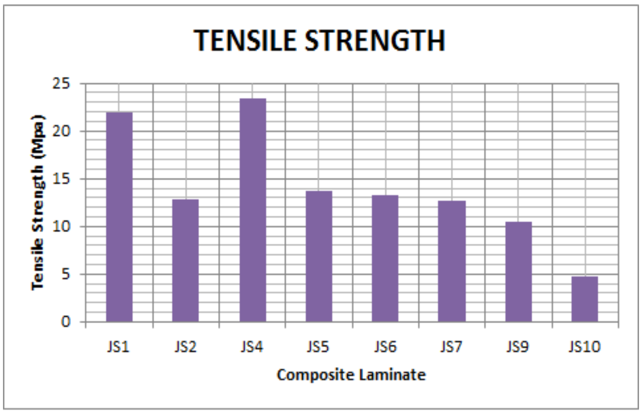

Figure 3: Representation of Tensile Strength of woven Jute fiber polyester Composite

Figure 3: The effect of fiber orientation and symmetrical arrangement of fibers on tensile strength. It is noted that composites have low tensile strength for symmetrical arrangement. Higher tensile strength is obtained for 4 layered (JS4) laminate with fiber angle orientation of 0°/15°/45°/75°. The tensile strength of (JS4) laminate is observed to be 23.43MPa with elongation % of 2.99%. The corresponding tensile modulus is 775.87MPa. This laminate breaks at peak stress point and doesn’t exhibit plastic property.

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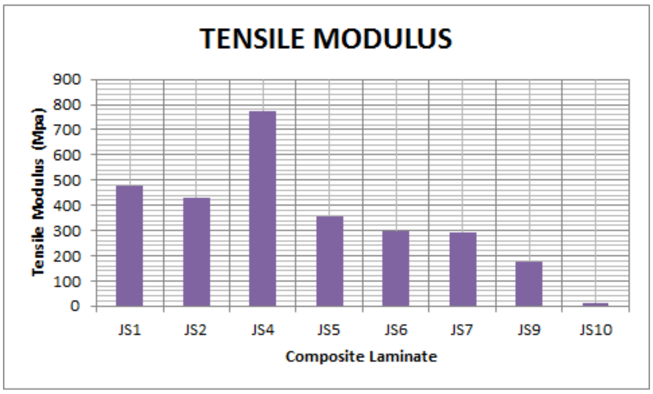

Figure 4: Representation of Tensile Modulus of woven Jute fiber polyester Composite

Figure 4: shows the variation of tensile modulus for each laminates. The tensile modulus varies irrespective of fiber orientation and symmetry of arrangements. The lower moduli are observed in laminates with symmetrical arrangements. Similar to tensile strength, the laminate (JS4) exhibits the higher tensile modulus. The main reason for high tensile strength and high tensile modulus of (JS4) laminate is the good adhesion between fiber with different angles and matrix.

Figure 5: JS4 Tensile Specimen Failure Pattern

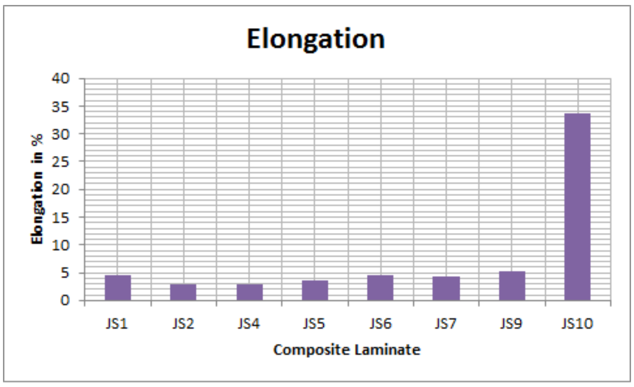

Figure 6: Variation of elongation percentage of woven Jute fiber polyester composite

Figure 6: Shows the elongation percentage of the laminates casted. All laminates exhibit same percentage of elongation except (JS10) laminate. This is observed due to more number of layers in laminate i.e. 10. The reason for it is the resin has not been distributed to all the layers equally and there

is poor adhesion between fiber and matrix, which leads to non-breakage of fiber and it goes on elongating exhibiting elastic nature.

Figure 7: JS10 Tensile Specimen Failure Pattern

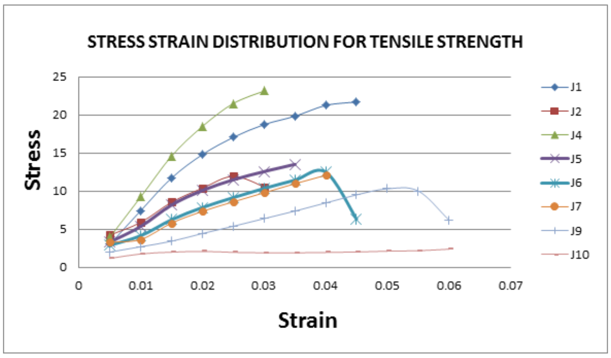

Figure 8: Variation of Stress strain for Flexure strength

Figure 8: Shows the variation of Stress strain for Flexure strength based on tensile strength Fig: 1 gives an outcome of tensile stress and tensile strain obtained from test carried out in UTM. Based on test curves obtained for all the laminates has been plotted. Initially yield stress increases with increase in stiffness of composite. For the laminates (JS5) and (JS6) initial drop is noted without secondary strength after peak stress. The remaining laminates get fractured without yielding when ultimate strength of material is reached due to brittle behaviour. These types of materials are not preferred when plastic deformation is required. The laminate (JS10) becomes constant at low loading rate which leads to low energy consumption.

Figure 9: JS5 Tensile Specimen Failure Pattern

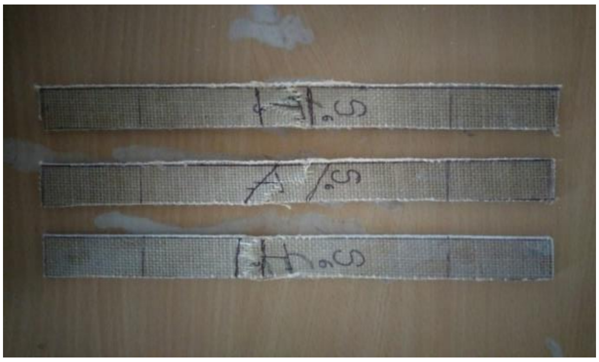

Figure 10: JS6 Tensile Specimen Failure Pattern

3.2 Flexural Properties

This test is conducted utilizing same computerized governor UTM of 5 tones capacity. Flexural samples were made by ASTM D7264 standards to know the flexural property. In the test specimen grip length is considered as 20 % of span length and span length is taken as 20 times of thickness. Test specimens dimensions are tabulated. Flexural specimens were tested in UTM with a strain velocity 10mm/minute. For peak value flexural property of sample is obtained. This test gives the bending behaviour of the specimen. The flexural strength is interpreted from the graph of load versus displacement.

The flexural strength is calculated from the formula

$$\text{Flexural strength, } \sigma = \frac{3PL}{2Bt^3}$$

$$\text{Young's modulus, } E = \frac{ML^3}{4Bt^3}$$

Where, P is load in KN, L is length in mm, B is width in mm, and T is thickness in mm

Table 3: Flexure strength and Modulus of woven Jute fiber polyester Composite

Symbol	Stacking Sequence	Number of ply	Thickness in mm	Ultimate Load (N)	Tensile Strength (MPa)	Tensile modulus (MPa)
FS1	0/15/30/45/60/75	6	5.51	50	20.92	464.51
FS2	0/30/60	3	3.35	24	16.53	615.38
FS4	0/15/45/75	4	4.36	56	29.64	816.62
FS5	0/30/45/45/30/0	6	4.62	22	10.99	302.74
FS6	0/15/30/30/15/0	6	4.85	22	10.52	252.18
FS7	0/45/45/0	4	4.04	58	33.13	959.47
FS9	0/15/45/75/75/45/15/0	8	5.84	26	10.27	223.89
FS10	15/30/45/60/75/75/60/45/30/15	10	6.61	22	7.56	299.89

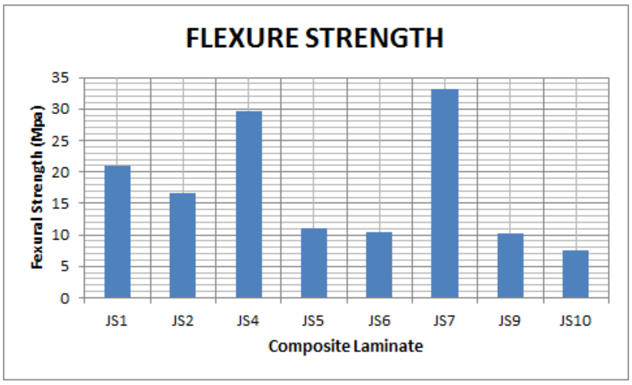

Figure 11: Representation of Flexure strength of woven Jute fiber polyester Composite

Figure 11: shows the flexure strength of different laminates. The higher flexure strength is observed in (FS7) laminate which is comprised of only 4 layers. The other laminate (FS4) also has higher flexure strength which is also comprised of 4 layers. From the graph we can say that as number layers increases low flexure strength is observed. This is proved when we observe the flexure strength of (FS10) laminate which is least among all the laminate. Reason for this is resin not distributed to inter-laminar layers properly. Thee flexure strength of (FS7) laminate of symmetrical orientation of 0/45/45/0 is highest.

The flexure strength was found to be 33.43MPa with flexure modulus of 959.47MPa. This laminate exhibits elastic property up to yielding point and breaks at fracture strain.

Figure 12: JS5 Tensile Specimen Failure Pattern

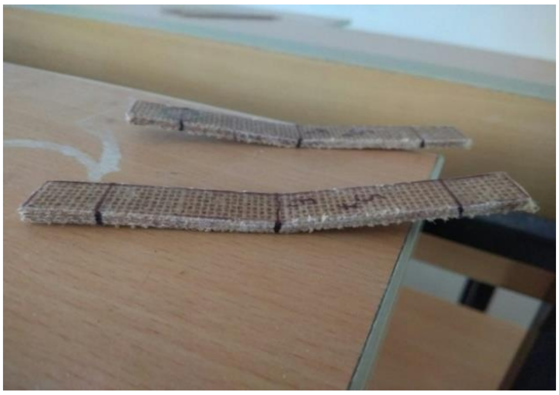

Figure 13: JS6 Tensile Specimen Failure Pattern

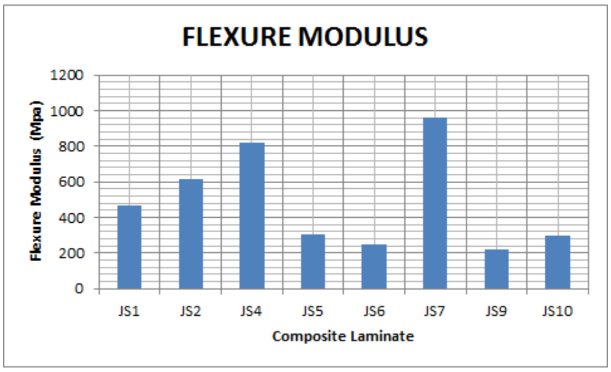

Figure 14: Representation of Flexure modulus of woven Jute fiber polyester Composite

Figure 14: shows the obtained Flexure moduli for the various laminates. Higher modulus is observed in (FS7) laminate due to higher flexure strength. Here also flexure modulus goes on reducing with increased number of layers. The highest two flexure modulus of laminates comprised of 4 layers only. Among them (FS7) has greater value due to symmetrical arrangements of Jute mats.

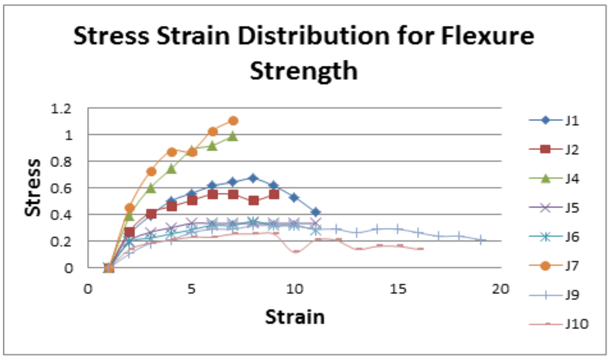

Figure 15: Variation of Stress strain for Flexure strength

Figure 15: Regarding Flexure test conducted we obtain the Flexure stress and Flexure strain. Corresponding graph is plotted with respect to the laminates. When we look into graph the laminates (FS4) & (FS7) shows elastic property and at yield stress it breaks at fracture strain. (FS1) and (FS2) show secondary strength after initial break point. The remaining laminates remains constant in plastic

region from initial point itself and breaks at fracture strain. As the number of layers is increased the laminates behaves as plastic material with elongation being extended.

Figure 16: JS4, JS7, FS2 Flexure Specimen Failure Pattern

4. Conclusion

In the present study the woven Jute polyester composite can be fabricated effectively by hot compression moulding mechanism. Unsaturated polyester Resin, Methyl Ethyl Ketone Peroxide and Cobalt Naphthenate of ratio 50:1:1 is very much sufficient to achieve the desired composite panel successfully. The tensile behaviour of laminate with different orientation is high and high flexure behaviour of laminate with symmetrical arrangements is noted. It is observed that the mechanical property of woven jute/polyester composite doesn't possess higher strength compared to conventional composites. But they do have higher strength than wood composites and some plastics. Since the reinforcing material used is eco-friendly and non-toxic, these can be used in indoor applications due to its lightweight property.

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