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Research Article

Influence of Naturally Originated Jute on the Fabrication & Mechanical Properties of Jute/Polyester Hybrid Composite

K. M. Faridul Hasan[1*], Mazharul Islam[1], Mohammad Neaz Morshed[1], Mst. Zakia Sultana[2], Md. Abdul Mueeid[1] and Ji-Hong Wu[1]

[1]School of Textile Science & Engineering, Wuhan Textile University, Wuhan, China
[2]School of Chemistry & Chemical Engineering, Wuhan Textile University, Wuhan, China

Abstract
Jute-Polyester reinforced Composited is fabricated through this research. The development of composite materials based on the reinforcement of two or more fiber types in a matrix leads to the production of hybrid composites. Jute cloth & Polyester resin were used to prepare the Jute/Polyester composites by hand lay-up and heat press molding techniques and their mechanical properties & behaviors were evaluated for different stacking sequences. In Jute/polyester mechanical properties such as tensile strength, bending properties and impact strength increase with the increases of stacking sequences. Water uptake (%) of this composite demonstrates that water absorption rate is initially higher for jute/polyester composite and at a stage it becomes steady (31.11%). Soil degradation test of all types of Jute/polyester were evaluated and the deterioration of the mechanical properties revealed for jute/polyester composites showed the higher degree but retained major portion of its original integrity and depicts the hybrid.

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***Correspondence to:** K. M. Faridul Hasan, School of Textile Science & Engineering, Wuhan Textile University, Wuhan, China
E-mail: farid_textile@yahoo.com

1. Introduction

Composites are combinations of materials differing in composition, where the individual constituents retain their separate identities. These separate constituents act together to give the necessary mechanical strength or stiffness to the composite part[1]. Through the combination of 2 or more material phases like disperse & matrix phases Composite material is composed. Matrix phase initially exist continuous character. Matrix is usually brittle & less hard material phase[2, 3]. It holds the dispersed phase and shares a load with it. Dispersed (reinforcing) phase is not seen in continuous form. This secondary phase is called the dispersed phase. Matrix is weaker than the Dispersed phase so it is often called reinforcing phase[4].

According to ASTM International Handbook Committee, 1973, composite material was defined as a macroscopic combination of two or more distinct materials, having a recognized interface between them. However, because composites were usually used for their structural properties, the definition were restricted to include only those materials that contain reinforcement (such as fibers or particles) supported by a binder (matrix) material. Composite material is also defined as a heterogeneous mixture of two or more heterogeneous phases which were bonded together [5].A composite material or a composite is a mixture of two or more distinct constituents all of which are present in reasonable proportions (> 5%) and have different properties so that the composite property is noticeably different from that of each of the constituents. Plastic is not a composite because it is a compound[6, 7].

The cellulose Fig. 1 , hemicelluloses and lignin all exist in the form of long chain molecules. In addition to these major components, it contains minor constituents such as fats and waxes, inorganic (mineral) matters, pectinious materials, nitrogenous mater, vitamins and traces of pigments like- carotene and xanthophylls. The chemical composition of jute fiber is shown in Table 3.3. The chemistry of jute refining prevails that jute is said to contain[8, 9].

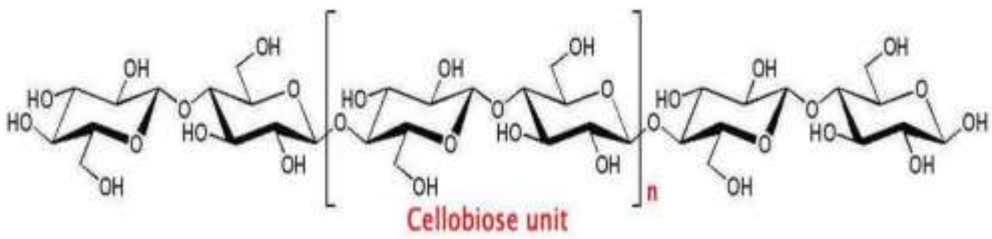

Fig. 1 Structure of cellulose molecule

The most important types of natural fibers used in composite materials are flax, hemp, jute, kenaf, and sisal due to their properties and availability. Jute is an important bast fiber with a number of advantages. Jute has high specific properties, low density, less abrasive behavior to the processing equipment, good dimensional stability and harmlessness. Jute textile is a low cost eco-friendly product and is abundantly available, easy to transport and has superior drivability and moisture retention capacity[10, 11].

Phenolic resins is the one of premier synthetic resin available commercially for fabrication & use of jute-composite products because of its higher resistance to heat, low smoke emissions, better fire retardance properties and compatibility with jute fibres or fabrics[12, 13]. Phenol-formaldehyde based jute composites products have been used for quite sometimes as wood and ceramic substitutes[14]. These pre-impregnated jute layers are arranged together for desired thickness and compression moulded at high pressure of 700-800 kg/m2 and at temperature of around 120-140℃. The modification is required to improve the wettability and compatibility of the fibre with resin matrix to produce strong fibre-matrix interface[15, 16].

2. Experimental

2.1. Materials

Jute woven fabric (Hessian Cloth, 1×1 plain weave) was used as reinforcement which was collected from the local market of Dhaka, Bangladesh. Unsaturated polyester resin collected from SHCP, Singapore. Methyl ethyl ketone peroxide (MEKP) collected from SHCP, Singapore.

2.2 Instruments

An electric balance (HP 200) was used for the measurement of weight of the samples. Hydraulic Press **(**Model: 3856, S/N: 3856-409**) is** for cold press, to control the current through the coil thereby controlling the temperature of the die. The composites were prepared by using an aluminum die. For removing moisture from composites specimen and jute hessian cloth Drying Oven (Model: AA-160, Denver Instrument Company) was used. To cut the composites for various testing the grinding machine was used. A universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD Series S, UK) range was used for quick and reliable tensile measurements. Universal Impact Tester (HUNG TA INSTRUMENT CO. LTD., Taiwan) is used for the impact strength test.

2.3. Methods

2.3.1. Preparation of composites

Initially jute woven fabric is cut at specified & desired size. As jute content moisture so it was dried at 100 ℃ for 1 hour in a drying oven. The matrix material was prepared by mixing unsaturated polyester resin and 10% MEKP, mixed thoroughly before applying in the fiber. Here, the composite is made by simple Hand lay-up method and then placed it with the aluminum dices in the hydraulic heat press machine for better curing and adhesion between fiber and polyester matrix at 90 ℃ for 10 minutes, then kept it at room temperature for 24 hours. Finally Jute- Polyester composite is made.

2.3.2. Determination of Mechanical Properties

2.3.2.1. Tensile Tests

Tensile test is a measurement of the ability of a material to applied forces tending to pull it apart and observe the extent of material stretches before breaking. The specimens are conditioned using standards of procedures. The recommended test conditions are 23±2 ℃ as a standard laboratory atmosphere and 50±5% relative humidity. Tensile strength **Table 1** of the composites was performed according to ASTM Designation: D638-03 .The test specimen was cut in a size length ≈ 120mm, width ≈ 15mm.As the specimen elongates, the resistance to the tension increases, and it is detected by a load cell. The tensile strength can be calculated by dividing the maximum load in newton's (N) by the original minimum cross sectional area of the specimen in square millimeters, and the result can be explained in the term of magapascal (MPa). The tensile strength at yield and at break (ultimate value) is calculated.

2.3.2.2. Bending Test

Flexural strength is the ability of the material to applied bending forces perpendicular to the longitudinal axis of the specimen. Two basic methods, including a three-point loading system utilizing center loading on a sample supported beam, and a four-point loading system utilizing two load points, are employed to determine the flexural properties. Static Bending tests were carried out according to ISO 14125 methods with cross-head speed of 60mm/sec and span distance 25mm.

2.3.2.3. Impact Tests

The impact properties of the polymeric materials depend mainly on the toughness of the material. Toughness can be described as the ability of the polymer to absorb applied energy.
Several methods are used to measure the impact resistance of plastics – Izod, Charpy, Gardner, tensile impact and many others. These impact tests allow designers to compare the relative impact resistance under controlled laboratory conditions and consequently, are often used for material selection or quality control. The Izod impact test is the most common test in North America. A pendulum swings on its track and strikes a notched, cantilevered plastics Sample. The energy lost (required to break the sample) as the pendulum continues on its path is measured from the distance of its follow through. Sample thickness is usually 1/8 in. (3.2mm) but may be up to ½ in. (12.3mm). Thickness of my sample was between 0.40 – 2.65 mm.

2.3.2.4. Water Uptake

Water uptake (wt%) of the composites were performed according to ASTM Designation: D570-99. The test specimen was cut in a size length ≈ 39mm, width ≈ 10mm. The prepared samples were kept in an oven at 105 ℃ for 1 hr. Composite samples were immersed in a static water bath at 25 ℃ for different time interval. After certain periods of time, samples were taken out from the bath and wiped using tissue paper, then weighed.

2.3.2.5. Soil Degradation Test

Composites samples were buried in soil (having at least 25% moisture) for 6 weeks. After 6 weeks, samples were withdrawn carefully, washed with distilled water and dried at 105 ℃ for 6 hours and kept room temperature for 24 hours and then measured the mechanical properties.

Table 1 Data for the mechanical properties of jute fiber reinforced polyester composites.

Symbol	Stacking Sequence	TS(MPa)	Eb%	TM(MPa)	BS(MPa)	BM(MPa)	IS(kJ/m²)
J1	J	69.9	3.6	3315	48.7	2965	12.23
J2	JJ	71.1	5.9	3793	119.1	3807	14.71
J3	JJJ	76.7	6.0	3610	114.4	3987	15.44
J4	JJJJ	81.8	6.7	4441	111.2	4876	19.41
J5	JJJJJ	88.4	8.0	3602	123.9	5182	20.97

3. Results & discussions

The employed process to prepare the specimens and the molecular orientation has a significant effect on tensile strength values. A load applied parallel to the direction of molecular orientation may yield higher values than the load applied perpendicular to the orientation. Injection molded specimens generally yield higher values than the samples molded in compression. As the strain rate, the change in strain value per unit time, is increased the ensile strength and modulus values increase. The tensile properties of some plastics change with small changes in temperature. Tensile strength and modulus decrease while elongation at break is increased by the temperature increase.

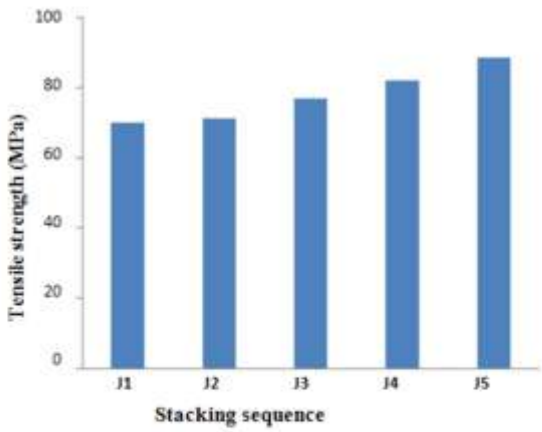

Fig. 2 Variation of Tensile strength (TS) with stacking sequence of jute-polyester composites

Fig. 2 shows that TS of J1, J2, J3, J4 and J5 are 69.9, 71.1, 76.7, 81.8 and 88.4 MPa respectively. The lowest value of TS is found for J1 is 69.9 MPa and the highest value of TS is found for J5 is 88.4 MPa. It is revealed that TS increased with the increase of stacking sequence of jute fabric in the composites.From Fig. 2, we see that, Eb% of J1, J2, J3, J4 and J5 composites are 3.6, 5.9, 6.0, 6.7 and 8.0% respectively, i.e. it increases with the increase of stacking sequences.

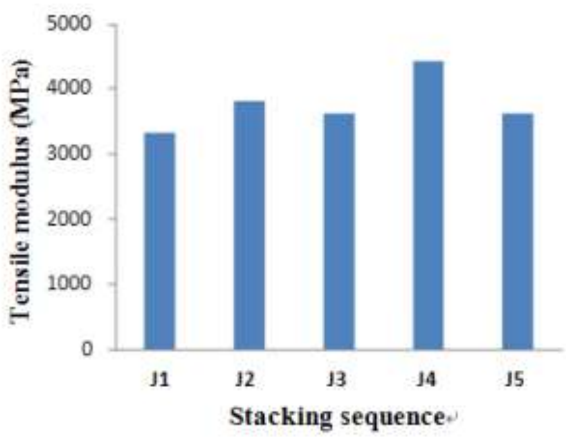

Fig. 3 Variation of Tensile modulus (TM) with stacking sequence of jute-polyester composites

According to Fig. 3, we can see that, TM of composites for J1, J2 increases, then for J3 slightly decreases, then for J4 increases and for J5 decreased again. The maximum TM is 4441MPa for four layers composite J4 and minimum TM is 3315MPa for 1 layer composite J1.The specimen with high degree of molecular orientation perpendicular to the applied load will show higher values than the one which is parallel to the applied load with the parallel ones. Another factor is the environmental temperature; there is an inverse proportion between it and the flexural strength and modulus. In addition, the strain rate (depend on tensile speed), sample thickness and the distance between supports (span) can affect the results.

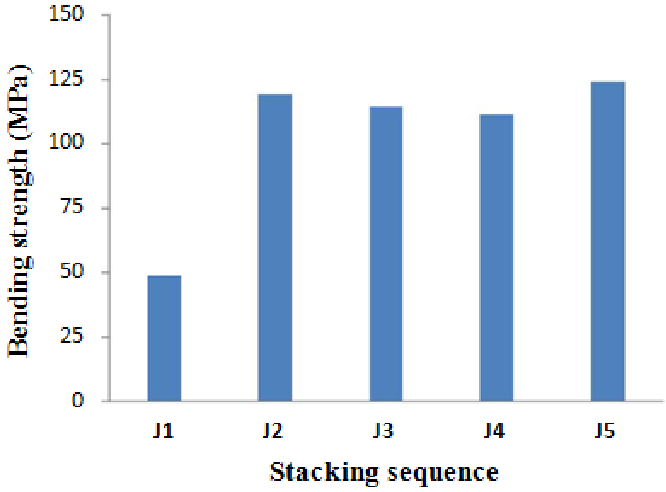

Fig. 4 Variation of bending strength (BS) with stacking sequence of jute-polyester composites

From the Fig. 4, we can see that, BS of J1 (1 layer) is very low (48.7MPa) due to its low thickness (0.50mm) and then it increases rapidly for J2 (2 layers, thickness 0.90mm) and little bit decrease for J3, J4, then increase for J5 up to 123.9 MPa Fig. 5.

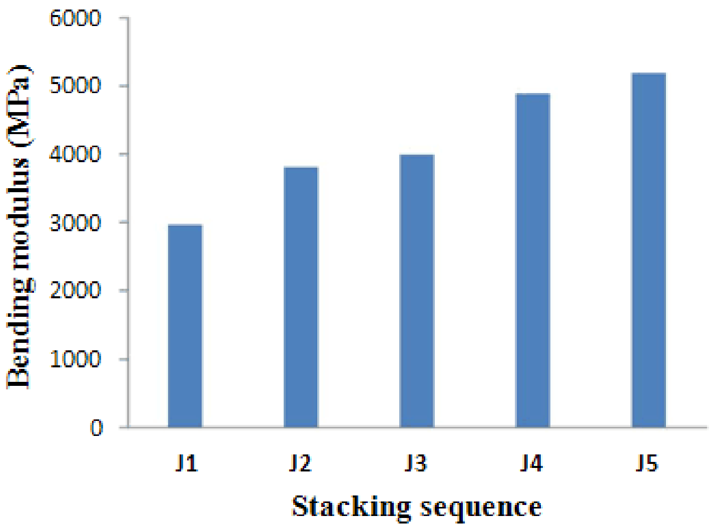

Fig. 5 Variation of bending strength (BS) with stacking sequence of jute-polyester composites

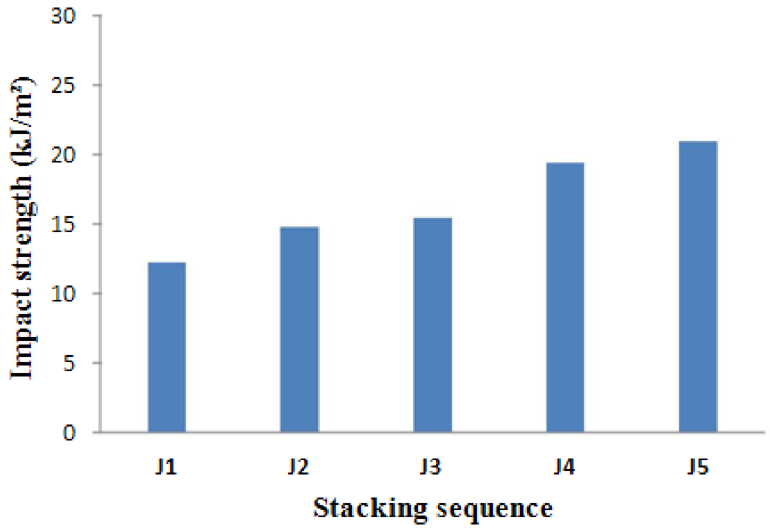

Fig. 6 Variation of impact strength (IS) with stacking sequence of jute-polyester composites

From the Fig. 6, we found that, IS of J1, J2, J3, J4 and J5 composites are 12.23, 14.71, 15.44, 19.41 and 20.97 kJ/m ^{2} respectively i.e. IS increases with increasing stacking sequences of jute fabric.The rate of loading has a significant effect on the behavior of the polymer during testing. At high rates of impact, even rubber-like materials may exhibit brittle failure.

Table 2 Data for water uptake (%) of jute fiber reinforced polyester composites.

Time (min)	Water Uptake (wt%)
0	0
5	16.56
10	16.89
20	17.67
30	18.00
50	18.89
80	19.44
120	20.67
180	21.33
240	22.22
1440	31.11
1500	31.11

All plastics are notch-sensitive. A notch or a sharp corner in a fabricated part creates a localized stress concentration, therefore, both the notch depth and notch radius have an effect on the impact behavior. Larger radius will have a lower stress concentration, resulting in higher impact energy Fig. 6 of the base material. The temperature increase lowers the impact resistance drastically. The impact strength is usually higher in the direction of flow. In addition, processing conditions and types play an important role in determining the impact behavior as well as in the case of degree of crystallinity, molecular weight and the method of loading.

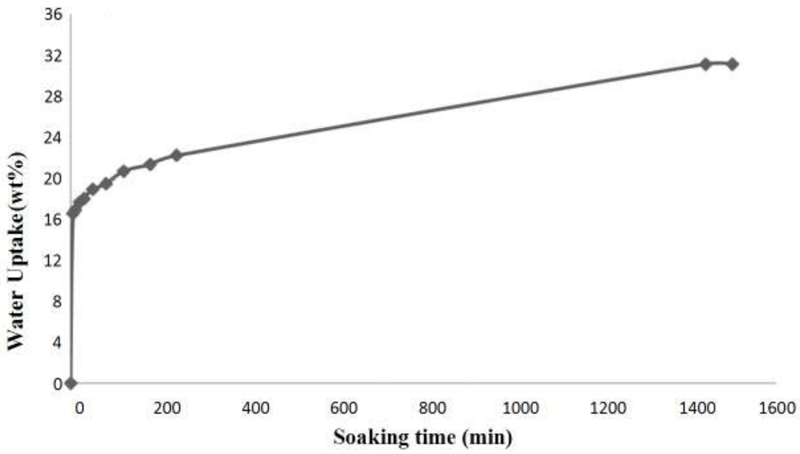

Fig. 7 Water uptake (%) of jute-polyester composites

Fig. 7 & **Table 2** show that water uptake for jute polyester composite up to 1500 minutes (25 hours). At first, the composite rapidly absorb water up to first 5 minutes, then it steadily increased 31.11% for 1500 minutes (25 hours) and then the absorption rate is very slow.

Table 3 Soil degradation test of Jute reinforced polyester composite (J5).

Mechanical Properties	Before 6 weeks	After 6 weeks
Avg. Tensile Strength (MPa)	88.4	60.8
Avg. Elongation at break (%)	8.0	3.6
Avg. Tensile Modulus (MPa)	3602	3048
Avg. Bending Strength (MPa)	123.9	103.5
Avg. Bending Modulus (MPa)	5182	4022
Avg. Weight (gm)	15.96	15.05

Through the soil degradation test it is seen that all the mechanical properties **Table 3** of the composite is reduced especially the Avg. Tensile Strength (MPa) is reduced from 88.4 to 60.8, Avg. Elongation at break (%) is reduced from 8 to 3.6, Avg. Tensile Modulus (MPa) is reduced from 3602 to 3048, Avg. Bending Strength (MPa) is reduced from 123.9 to103.5, Avg. Bending Modulus (MPa) is reduced from 5182 to 4022, Avg. Weight (gm) is reduced from 15.96 to 15.05.

4. Conclusions

Experiments were performed to analyze the effect of jute and polyester fiber stacking sequence on the mechanical properties of jute/polyester composites hybrid composites. Also water uptake (%), soil degradation and effect of gamma radiation were studied. In jute/polyester composites effective result is found based on the mechanical properties. Such as mechanical properties of the jute/ polyester composites is improved with the increase of stacking sequences. Water uptake (%) of jute polyester composite also exhibits higher values. In soil degradation test, it has been found that jute/polyester composite is biodegradable.

Jute fiber surface could be modified using by various chemical agents to increase its tensile properties. The experiment could also be performed by using other matrix polymer such as vinyl ester, epoxy resin as thermosetting and polypropylene, LLDPE as thermoplastic matrix. Jute fiber surface could also be modified by UV, Gamma radiation or Plasma treatment to increase its tensile properties.

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