Proceedings of the
International Conference on Mechanical Engineering 2005
(ICME2005) 28- 30 December 2005, Dhaka, Bangladesh

ICME05-AM-42

INVESTIGATION OF MECHANICAL PROPERTIES OF POLYESTER RESIN MATRIX COMPOSITES REINFORCED WITH LOCALLY AVAILABLE JUTE MAT

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ABSTRACT

Natural fiber especially jute has gained paramount attention recently for use as reinforcing agents in composite materials. Glass polyester composite and jute polyester composites were fabricated by hand lay-up technique with glass mat and woven jute mat of different treatment conditions respectively as reinforcing agents. The mechanical properties like tensile and flexure strength were measured for these composites and compared. Significant improvement in tensile and flexure strength of the full bleached jute mat composite has been observed. The nature of the fiber-matrix adhesion could be established from the result of scanning electron microscopy of fracture surface and FTIR of composites. Surface treatments may improve the compatibility and strengthen the interface in natural fiber composite materials and lead to improvement of the stress transfer efficiency at the interface.

Keywords: Surface treatment, Mechanical properties, Crack profile.

1. INTRODUCTION

Jute as a natural fibre has been traditionally used for making twines, ropes, cords, as packaging material in sacks & gunny bags, as carpet-backing and more recently, as a geo-textile material in Bangladesh. But, lately the major share of its market has been declined by the introduction of various synthetic materials. Jute fibre due to its adequate tensile strength and good specific modulus enjoys the right potential for usage in composites. The vast potential for the use of natural fibers viz. jute in fiber-reinforced composites has lead to an increasing interest for high value added products, such as in household, packaging, structural materials for housing, railways, automobile products etc. The idea of producing long lasting composite materials made of jute fibers has not been considered in the past, because of its rotting, swelling and burning properties. It is now found that application of jute fibers for composites has many advantages. Jute fiber is renewable, versatile, non-abrasive, biodegradable, and compatible.

Jute fibre is hydrophilic in nature (i.e. strong affinity for water) which causes poor wetability with hydrophobic organic matrix resins like polyesters when preparing composites. The reverse nature of the jute and polymer matrix create difficulties in compounding and result composites of poor mechanical properties [1]. In order to develop jute composites with improved performance characteristics, hydrophilicity nature of jute fiber is reduced by chemical modifications like alkalization, bleaching, grafting etc. These treatments not only decrease the water absorption capacity of the fibre but also increase the wetability of the fiber with resin and improved interbond strength between fibre and matrix [2]. For improved fibre-matrix interaction, several types of coupling agents or additives of different chemical nature were used to modify the jute surface. Bleaching of jute fiber with sodium chlorite has been carried out [3] to decrease its hydrophilicity and brings better adhesion between fiber and polymer matrix. MAPP[4]] was used by different researchers for surface modification of jute and kenaf. Khan et al used vinyl vinyl monomers like 2-ethyl hexyacrylate (EHA) and 2-hydroxyethyl methacrylate (HEMA) as additives in jute plastic composites with enhanced mechanical properties[5-8].

Interest in using jute fibres as reinforcement in polymer matrices as partial replacement of glass fibers has grown significantly in recent years for making engineering and non-engineering structures. The main goal of this project is to fabricate natural fiber-reinforced polymer composites and to investigate adhesion and interfacial bond characteristics with a view to optimizing key properties. The results obtained in this project are likely to be sustainable based on the country's utilization of natural resources and need for industrial growth.

2. EXPERIMENTAL

2.1 Collection of Materials

The woven jute fabric namely, retted jute fabric (RJ), full bleached jute fabric (FBJ) and half bleached jute fabric (HBJ) were collected from Bangladesh Jute Mills Corporation (BJMC). Each square inch of the woven jute fabric contains 15 yarn / 15yarn placing its position 90° apart each other forming the fabric. The chopped strand mat of glass fiber (GF) of 300gm/m^2 was collected from the local market that was imported from Singapore Highpolymer Company Ltd (SHCP). The specification of the resin is general-purpose unsaturated polyester (ortho) roof grade and was obtained from Singapore Highpolymer Chemical Products Pte Ltd (SHCP).

2.2 Composite Fabrication

Jute fabric-polyester and glass fabric-polyester composites were prepared by hand lay-up method. At first coat of the resin was applied on the waxed plastic sheet. The mat was placed on the top of that and the resin was applied on the mat by using the brush. The serrated roller was then used to even out the resin and remove any entrapped air in the resin. The woven fabric layer is placed on top of the first layer, and the above process was repeated. After the final layer of mat is laid, it is covered with a waxed plastic sheet, and a flat glass plate is placed on the top with a weight to ensure a smoother surface and the fabricated composite is allowed to sit for the required time for cure. As the volume of the each ply are different for fabrics, composites are vary in vol% while the jute composites of different fabrics are made from 13 ply of mat. Samples prepared from cured polyester, glass fiber reinforced polyester, retted jute mat reinforced polyester, half bleached jute mat reinforced polyester and full bleached jute mat reinforced polyester composites are designated as RP, GFPC, RJPC, HBJPC and FBJPC respectively. vol% of fibers in composites, bulk density of the composite and void in % in composites and % water absorption of composites are given in Table 1.

Table 1: Physical properties of composites.

Sample	**vol.** %	**bulk density,** gm/cc	**void** %	**Water absorption** %
RP	-	1.03	1.23	0.11
GFPC	16.8	1.28	0.84	0.02
RJPC	19.0	1.09	1.00	1.43
HBJPC	19.5	1.08	0.94	2.50
FBJPC	21.0	1.09	0.90	2.28

2.3 Mechanical Testing

Tensile tests in accordance with ASTM D3039 were carried out for polyester and composite samples of 250mm long, 25 mm wide and 12.5 mm thick in a UTM testing machine (Shimadzu-500KNA) in order to determine the tensile properties. Three point bend tests were performed also in UTM in accordance with ASTM D790 to measure the flexural strength of the composites. Test specimens were 250mm long having a width of 25 mm , thickness of 12.5 mm and a loading span of 160 mm was employed. For both tests a cross head speed of 2mm/min was employed.

2.4 Scanning Electron Microscopy

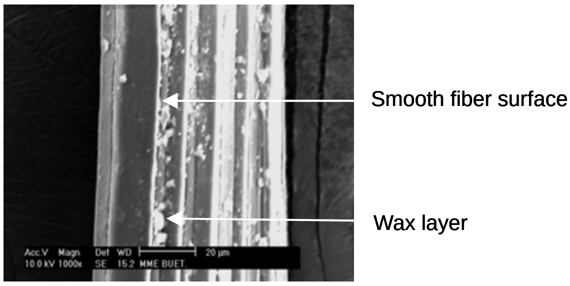
In order to assess the effect of the treatment upon jute fiber surface, fibers were examined in an XL – 30 Philips Scanning Electron Microscope (SEM). A vacuum unit sputter coater was utilised to deposit a thin metallic layer of gold of 70nm thickness on the fibers. Scanning Electron Microscope (SEM) was also utilized to characterize the fracture surface, crack profile of composites.

2.5 Fourier transform infrared spectroscopy (FTIR)

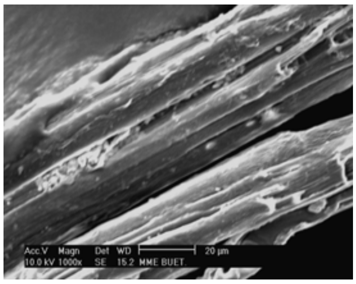
Retted and bleached jute fabrics and the composites were analyzed by FTIR (Model FTIR 8400S, Shimadzu Corporation) using attenuated total reflectance technique. This test was carried out with a view to analyze the bonding characteristics between the fiber and the matrix.

3. RESULTS AND DISCUSSION

The surface topography of jute fibers of both retted jute and retted and bleached jute fiber were analyzed by SEM and the SEM pictures of these fibers are shown in Fig. 1.



(a)



(b)

Fig 1. SEM micrograph of (a) retted jute fiber and (b) full bleached jute fiber

The surface of retted fiber is smooth and covered by thin layer of wax where as rough surface due to voids and absence of wax on the surface of the bleached fiber were observed. The change in surface topography of bleached fiber may result in effective bonding between fiber and polyester matrix.

The FTIR spectra of retted and bleached jute fibers are shown in Fig 2. Although bleaching treatment on jute fabric removes wax , xylene etc [7] but the characteristics absorption band for retted and bleached jute fiber shows no significant difference.

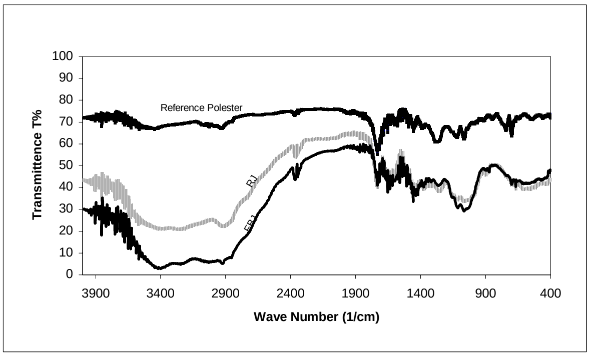


Fig 2. FTIR spectra of reference polyester, retted jute (RJ) and full bleached jute (FBJ).

The mechanical properties of composites are included in table 2. For each data point minimum four samples were tested and the value given is the mean of those results. Table 2 infers the increase in strength and stiffness values of the woven jute fabric reinforced laminated composite specimens then the reference polymer.

Table 2: Mechanical properties of composites**.**

Sample	**Tensile Strength,** MPa	**Flexural Strength,** MPa	**Flexural Modulus,** GPa
RP	18.62	47.32	4.92
GFPC	91.40	179.04	6.76
RJPC	28.81	53.34	3.41
HBJPC	21.94	69.04	3.78
FBJPC	25.55	50.24	3.58

Figure 3 shows the flexural load-displacement diagram of polymers and composites. It can be noted that composite with retted jute fabric has almost the same flexural properties to that of cured polyester and the half bleached jute fabric reinforced composite shows the highest flexural properties among the woven jute fabric reinforced composite.

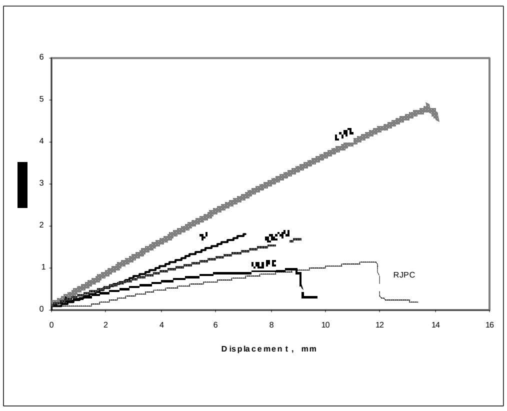


Fig. 3. Flexural load-displacement curves of reference polyester and composites reinforced with glass and jute mat.

Variation in flexural strength and displacement can be explained by the nature of the crack propagation (Fig 4.[a] & [b]) during failure of composites. Fracture of the composites are characterized by the cracking of matrix till it encounters the jute mat. The fiber bundles parallel to the tensile loading in the mat debond from the matrix as a result of shearing between fiber and matrix. Decohesion of the fiber from the matrix joins the crack front. As the crack front change its direction, stress concentration at the crack tip helps to separate the crack bundles which are perpendicular to the loading direction. Eventually matrix fails and the crack is bridged by the fiber bundles which are orthogonal to each other and finally the embedded yarns those are perpendicular to the loading direction pull out from the matrix.

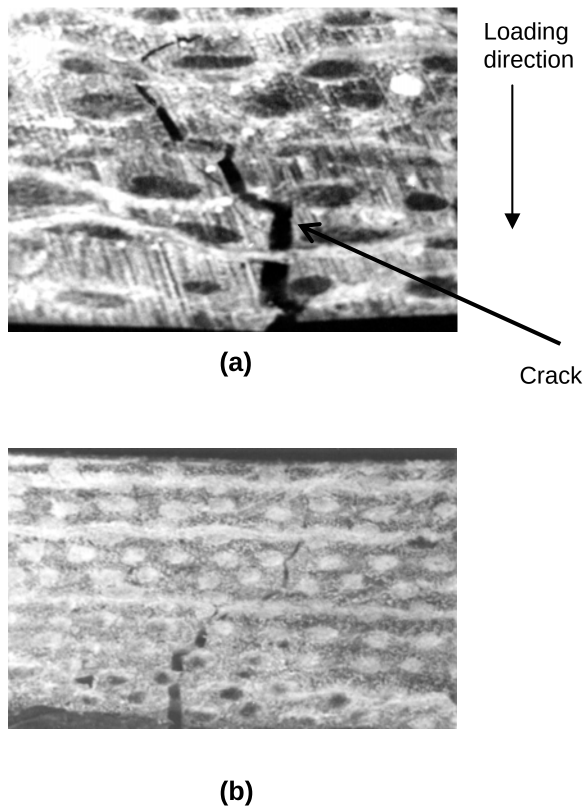


Fig 4. Crack profile of (a) RJPC and (b) FBJPC after failure in flexure test.

Progressive motion of the crack front through steps and gradual change in crack opening attribute the higher ductility in the composites. Fibre pullout and debonding of fiber bundles of both directions are also found in SEM pictures (Fig. 5 [a-c]). For glass fiber composite extensive fibre pull out is observed due to its high compatibility with matrix but in the case of jute mat composites a large area is delaminated before the fibre pull out has taken place and much lesser strength is observed. Treatment of fibre mat may increase the compatability and the flexural properties are higher than that of untreated mat.

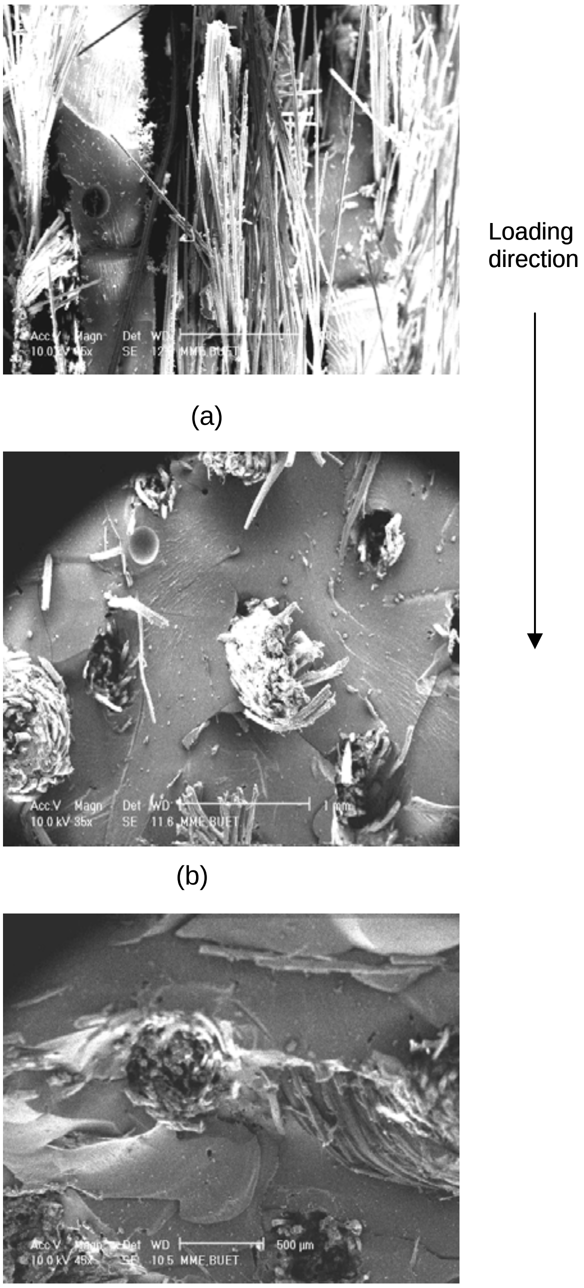


Fig 5. SEM fractographs of (a) GFPC, (b) RJPC and (c) FBJPC.

Figure 6 shows the comparison of the FTIR spectrum of the reference polymer, RJPC, HBJPC and FBJPC. The blunt headed intense peak for ester group appeared at wavenumber of 1732.0 cm^{-1} for RJPC. For HBJC and FBJC the C=O absorption band of saturated aliphatic esters (except formats) with blunt appearance is present in the 1750 – 1735cm^{-1} region. If a comparison is made between the spectra, it is found that the percentage transmittance of the FBJC is the lowest i.e. highest IR absorption in the ester region. This indicates the formation of ester is enhanced upon bleaching treatment and ensures good chemical interaction with the resin, but since, the chemical treatment removes the binders of fiber so its modulus increases but strength decreases which is also reported in previous work [7].

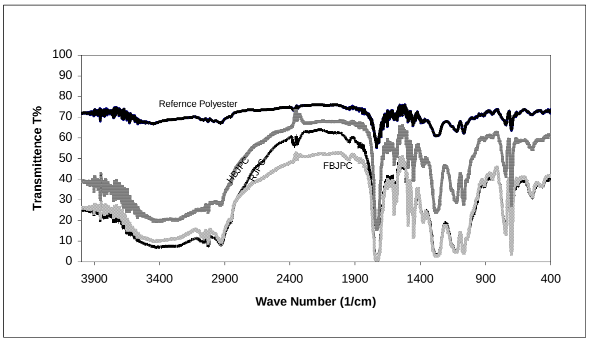


Fig 6. Comparison of FTIR spectra of RP, RJPC, HBJPC and FBJP.

4. CONCLUSIONS

Difference in surface condition of treated and non treated jute has been observed. The composites reinforced with treated fiber mat showed improved flexural strength. The SEM studies of the fiber surface of the full bleached jute show how the fiber surface is effectively leached off the binding materials due to the treatments.

Failure mode of woven jute fabric was also interface dependent. During tensile test the yarn that lie perpendicular to the load direction acted as flaw and non-load bearing component of the composites. These yarns were also acted as a source of defect when the composites were loaded transversely. During flexural test these yarns lie parallel to the loading direction. Both these fact lowers the effective volume fraction of fiber in woven jute fabric reinforced composite. Flexure fracture profile showed that the crack tip acted through these node points to ensure failure of these composites. Fiber pullout was prevalent mode of failure for tensile test with little shearing. Severe shearing and fiber pullout was seen in case of flexural test. Bleached variety of woven jute fabric showed little amount of polymeric residue on the fiber surface due to good fiber matrix compatibility and is an effect of bleaching treatment.

5. ACKNOWLEDGEMENT

Assistance provided through an VlIR-ABOS project by the Belgian Agency for Development Cooperation and Bangladesh Council for Scientific and Industrial Research are gratefully acknowledged.

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