

FABRICATION, PROCESSING AND MECHANICAL PROPERTIES OF FLAT BRAIDED THERMOSETTING COMPOSITES USING NATURAL AND COATED JUTE YARN

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Abstract

This paper submits investigation on the tensile and bending properties of the flat braided thermosetting composites made using jute yarns. Combining flat braided jute yarns (untreated and coated) and vinylester resin, composite specimens were manufactured by hand lamination method. Tensile and 3 point bending tests were conducted. Test samples were polished and pre- and post-failure examinations were carried out using optical and scanning electron microscopy in order to analyze the test results and their relationships to the state of resin impregnation into the fibre bundles, fibre/matrix interfacial properties and the fracture and failure mechanisms. While tensile properties were slightly degraded due to coating treatments, bending properties of the composite showed improvement when coated yarns were used. These variations in the mechanical properties were broadly related to the state of resin impregnation into the fibre bundles and/or fibre/matrix interfacial interactions.

Introduction

The increasing global interest on the new structural materials from the natural sources, with the new economic climate turning attention to larger volume industrial uses, is mainly driven by the conservation of forest and forest resources through reducing its massive usage, and the need for the cost reduction in raw materials, manufacture and maintenance of composites. With a view to replacing the wooden fittings, fixtures and furnitures, natural composites reinforced with jute, kenaf, sisal, coir, straw, hemp, banana, pineapple, coconut, rice husk, bamboo etc. can be used instead of the conventional polymer composites reinforced with man-made fibres such as glass, carbon, aramid etc. Until recently, there has been only limited information available towards understanding the behaviour of composites reinforced with natural fibres. Jute is one of the most common agro-based fibres that has enormous potential in composite manufacture due to its cost-effective, renewable, versatile, nonabrasive, viscoelastic, biodegradable, combustible, compostable and insulating characteristics. Mohanty and Misra [1] reviewed thermosets, thermoplastic, and rubber-based

composites reinforced by jute fibre. Dewaxing, alkali treatment, bleaching, cyanoethylation and grafting are used to modify the surface of the jute fibre/fabric in an attempt to improve the hydrophobicity of the fibre so as to obtain good fibre-matrix interfacial bonding. Low viscosity polyester reinforced with bleached jute resulted in the exceptionally high tensile, flexural and interlaminar shear strength properties [2]. Full-bleaching treatment improved interfacial adhesion characteristics of jute surface by removing natural and artificial impurities thereby enhancing strength properties of the resultant composites [3]. Flexural behaviour of natural fibre reinforced thermosetting composites was studied by several researchers [4-10]. Impact fatigue behaviour [11] of jute/vinylester composites and fatigue behaviour of jute/epoxy [12] composites were studied using untreated and alkali treated jute fibres. Flexural strength and impact fatigue properties were improved due to increased interfacial bonding and fibre strength properties by alkali treatment. The jute fibre reinforced composite products are not severely affected by mites, moisture, and are generally considered to be fire-retardant and chemical-proof. This paper reports investigation by tensile test, 3 point bending test and fractographic studies to evaluate the mechanical performance and characterize the behaviour of flat braided jute fabric reinforced vinylester composites using natural and coated (polished) jute yarns.

Experimental

Materials, Fabrication and Mechanical Tests

Jute yarns (both natural and coated) from 100% BT Tossa B-grade finer jute fibres were supplied by Bangladesh Janata Jute Mills Ltd. The coating agents used were PVA (Poly vinyl alcohol) and PP (Poly propylene) each with 1.5% weight content of the jute yarn. Natural and coated jute yarns were braided to produce 15 mm wide flat-braid fabrics using 25 spindles. Table 1 summarises the differences in the reinforcing yarns and the test results. Flat composite specimens of 1 mm nominal thickness were fabricated using vinylester resin (Ripoxo R806-B, supplied by Showa Highpolymer Inc.) by hand lamination method. The specimens were cured at room temperature for approximately 24 hours under clamped condition,

followed by another 24 hours postcure at 100°C. Spacers were used in the lamination tool to ensure that the required nominal specimen thickness of 1 mm was obtained. Straight-sided tensile specimens of 180 mm × 15 mm nominal dimensions were used for this study. Bending specimens were 15 mm in nominal width and the span length was 20 mm. Both tension and 3 point bending tests were conducted on an Instron Universal Testing Machine (Type 4206) under a nominal test speed of 0.5 mm/min and 1 mm/min, respectively. Tensile specimens were clamped over an area of 40 mm × 15 mm at each end leaving a gauge length of 100 mm. An open mesh emery cloth (Polynet sheet – 240 grit) was used in the gripped areas instead of aluminium end tabs. Strain was measured using strain gauges, which were bonded onto the central surface of the specimens. No fewer than five specimens were tested for each specimen type. Tensile and bending properties were determined from the tests. Pre- and post-failure examinations were carried out on selected test specimens using an optical and a scanning electron microscope (SEM) to study the fibre-matrix interfacial adhesion, state of resin impregnation into fibre bundles and fracture phenomena to characterize failure mechanisms in the flat braided jute composites.

Results and Discussion

Typical stress-strain curves shown in Fig. 1a, clearly indicate tensile failure in a brittle manner. Tensile and bending test results were summarized in Table 1. Tensile strength and stiffness were graphically presented in Fig. 2. Tensile properties were slightly degraded, whereas bending strength and stiffness improved considerably and marginally (Fig. 3), respectively, for the composites made using coated jute yarns. This different trend exhibited by the bending test (Fig. 1b and Fig. 3) could be attributed to the differences in failure mechanism and the interactions between the fibre/matrix interfaces. Both un-coated and coated specimens exhibited normal tensile failure (Fig. 4a). Bending samples failed in both tensile (Fig. 4b) and compressive (Fig. 4c) manner. Natural (un-coated) jute yarn composites revealed better matrix fusion into the fibre bundles than that of the coated yarn composites, as exemplified in the optical micrographs of the polished cross sections (Figs. 5a and 5b). Figs. 6 describe tensile fracture phenomena using SEM micrographs of the fractured surfaces. There were clear evidences of brittle failure in Figs. 6a and 6d. While comparing Fig. 6b with Fig. 6e, it can be noticed that in the case of natural (un-coated) jute composite, there were evidences of matrix adhesion to the fibre bundles and fibre splintering after pull-out. This indicates a better fibre/matrix interfacial interaction. On the other hand,

clear fractured surface of the coated yarn composite (Fig. 6e) indicates inferior fibre/matrix interfacial bonding. Good resin impregnation around the fibre bundles were evident in Fig. 6c, due to good interfacial interaction between the cellulosic fibre surface and the polar vinyl ester matrix. On the contrary, a clear surface after matrix peel-off was seen (Fig. 6f), which indicates that coating did not contribute positively towards interfacial properties. With the coating of PVA/PP on the jute yarn, it is expected that the PVA would form hydrogen bonding with the cellulosic fibre surface exposing PP, which will be repelled by the hydrophilic fibre surface, and does not interact with the vinyl ester matrix due to the differences in the polarity. This resulted in the poor interfacial bonding. Bending test specimens having uncoated jute yarns exhibited both tensile and compressive failure leading to the final failure of the composite in a brittle manner (snap-out phenomena) indicating good interfacial properties, as exemplified in Figs. 7a and 7b, whereas in the coated yarn composite, ultimate failure did not occur. Matrix failure followed by fibre-slippage or fibre towslipping by the shearing effect was evident in Figs. 7c and 7d. This fibre-slippage was caused again by the poor interfacial bonding promoted by the presence of the non-polar PP-coating in contact with the polar vinyl ester.

Conclusion

Tensile properties were slightly degraded, whereas both bending strength and stiffness improved for the composites made using coated jute yarns. These variations in the mechanical properties were broadly related to the state of resin impregnation into the fibre bundles and/or fibre/matrix interfacial interactions.

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Tables & Figures

Table I: Summary of the reinforcing materials and test results

Sample ID	Quality	Average Yarn Count (N)	Average Yarn Breaking Load (N)	Average Yarn Breaking Strength (MPa)		Composite Fibre Content V_f	Composite Tensile Strength (MPa)	Composite Tensile Modulus (GPa)	Composite Tensile Strain-to-failure	Composite Bending Strength (MPa)	Composite Bending Modulus (GPa)
				Jute Mill	KITLAB						
NJ_FB_VE	7 Lbs/1 Ply Natural Yarn 100% Tossa	31.5	30.9	185	22	22%	87	5.7	0.020	137	5.6
CJ_FB_VE	7 Lbs/1 Ply PP Coated (Polished) 100% Tossa	31.8	33.5	145	21	21%	79	5.2	0.018	163	6.1

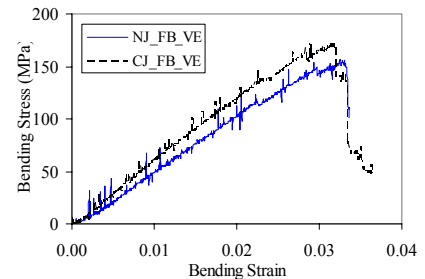
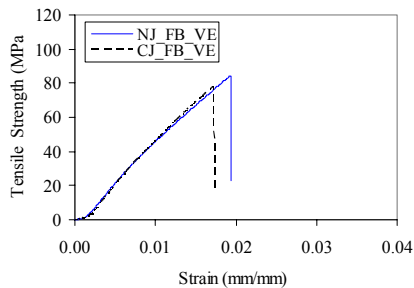


Figure 1: Typical Stress-Strain Characteristics (a) Tensile (b) Bending

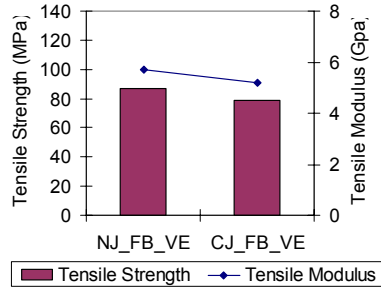


Figure 2: Tensile Properties affected by coated jute yarn

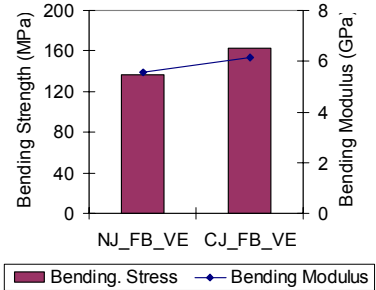


Figure 3: Bending Properties affected by coated jute yarn



Figure 4: Fractured test specimens (a) Tensile specimens (b) Tension side of Bending (c) Compression side of bending

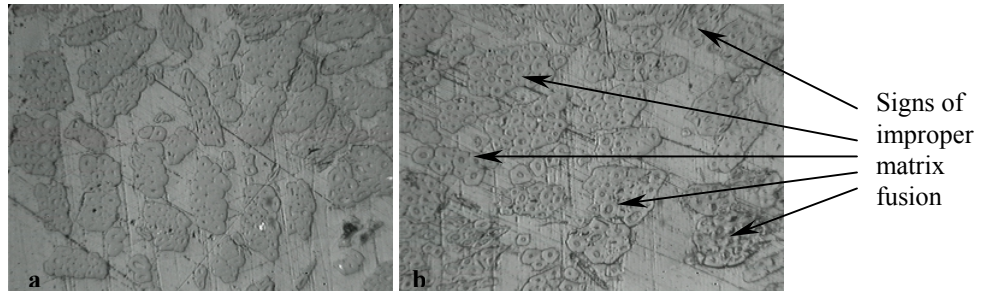
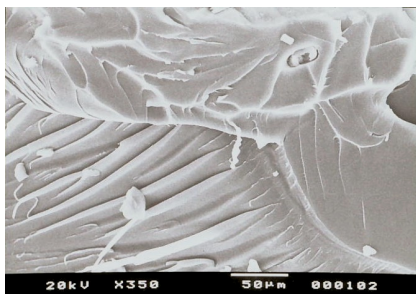
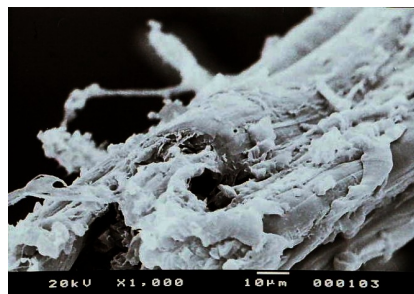


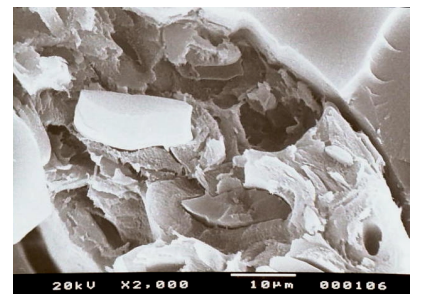
Figure 5: Optical micrographs of the polished cross section prior to test (a) Natural (b) Coated



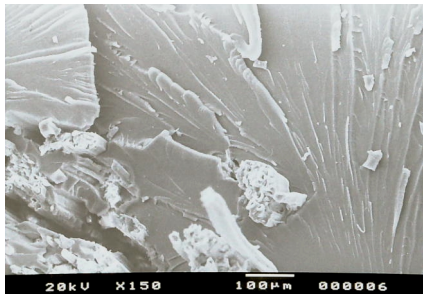
(a) Evidence of brittle fracture



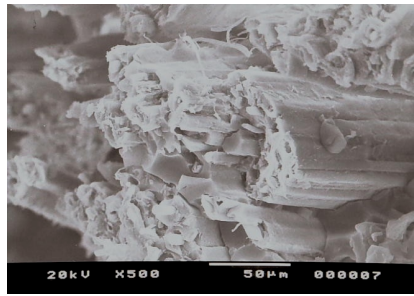
(b) Matrix adhesion to the fibre bundles and fibre splintering after pull-out due to good interfacial bonding



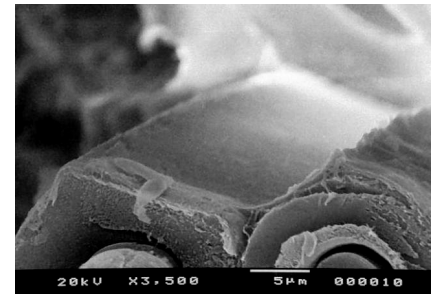
(c) Better resin impregnation around the fibre bundles



(d) Evidence of brittle failure



(e) Clear fracture surface due to poor interfacial bonding



(f) Poor fibre/coating/matrix interfacial interactions

Figure 6: SEM micrographs describing tensile fracture phenomena (a,b,c) Natural jute (d,e,f) Coated jute

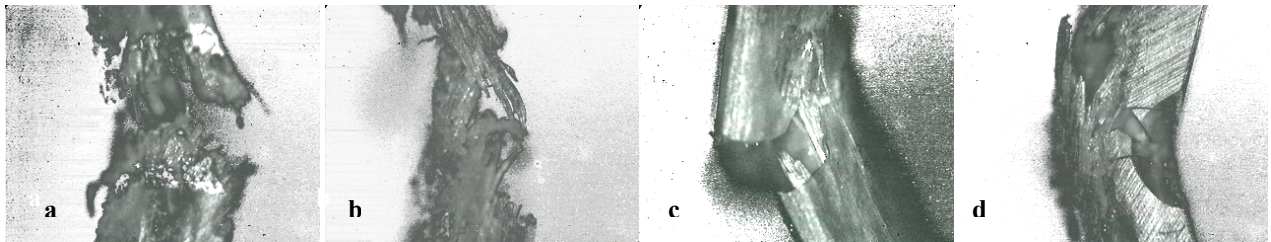


Figure 7: Bending failure (a,b) Natural un-coated jute composites (c,d) Coated jute composites