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MEASUREMENT OF PERMEABILITY OF WOVEN JUTE FABRICS AND EVALUATION OF MECHANICAL PROPERTIES OF JUTE FABRIC-REINFORCED COMPOSITES

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SUMMARY: Permeability study was carried out using jute fabrics (natural and bleached) through a resin transfer molding (RTM) technique. Unsaturated polyester resin and a mixture of corn syrup, water and a water soluble dye was used for the study. Both infusion and injection methods were employed. Darcy's equation was used for permeability evaluation. The permeability of bleached fabrics was smaller than natural fabrics. Permeability values of injection experiment disagreed with that of infusion experiment. Permeability decreased with increase in fiber volume fraction for both type of fabrics. Composites were fabricated using unsaturated polyester resin. Mechanical properties of the composites were evaluated. Considerably better mechanical properties were observed in case of bleached jute composites. A stronger fiber-matrix adhesion was observed in the SEM picture of bleached jute composites. More fiber pull outs were observed in the scanning electron microscopy of natural fabric composites indicating a weaker interface.

KEYWORDS: permeability, natural, bleached, jute fabrics, Resin Transfer Molding (RTM)

INTRODUCTION

Due to the increasing environmental consciousness, natural fibers are attracting considerable demand as reinforcing material in composite industries during recent years. Jute, one of the most common natural fibers, has enormous potential in composite manufacturing. However, surface topology, chemistry of fibers, fibers properties, weaving technique and architecture of fabrics greatly affect the properties of fibers-reinforced composites. Different processing techniques are

being used for the manufacturing of natural fibers based composites. Resin Transfer Molding (RTM) is one of the promising techniques because of short cycle time and its capability to make complex parts. Permeability measurement of jute fibers has been reported by researchers [1]. In the present study RTM method have been used for composite fabrication and the measurement of permeability of jute fabrics. The effect of bleaching treatment of fibers on the permeability and on the tensile properties of the composites was studied.

EXPERIMENTAL

Materials

Untreated (natural) and chemically treated (bleached) jute fabrics with sample code 3.5 lbs /single (~1.59 kg/single for both the fabrics) were supplied by Sonali Aans Limited, Bangladesh. Average areal weight was 0.231 kg/m^2 for natural and 0.244 kg/m^2 for bleached jute fabrics. Unsaturated polyester and mixture of corn syrup with water and one water soluble dye were used for permeability measurement. Butanox M-50 and cobalt octoate were used as accelerator and catalyst respectively during the use of unsaturated polyester resin in composite fabrication.

Experimental Set up and Permeability Study

Unidirectional flow experiments were carried out. Different infiltration experiments such as, infusion experiments with vacuum and injection experiments were carried out using polyester resin. During infusion, 3 layers of jute fabrics (0.24-0.25 fiber volume fraction) with dimension of 400mm in length, 150mm in width and 2mm thickness were used to make preforms. During injection, 4 layers of jute fabrics (0.32-0.33 fiber volume fraction) with dimension of 150mm in length, 180mm in width and 2mm in thickness were used to make preforms. Experimental parameters are shown in Table1. Above said parameters were used for experiment with polyester resin only. In case of corn syrup mixture, the dimensions of jute fabrics were 250mm in length, 50mm in width and 3mm in thickness. The number of layers in the preforms was 5, 6and 8 for natural jute fabrics and 5, 6 and 7 for bleached jute fabrics. Experimental parameters for this experiment were as follows: 10 psi (68947.6 Pa) pressure, 25.8 - 41.3 fiber volume fractions and 0.251 Pa.s viscosity of the fluid. Permeability of jute fabrics were studied by varying viscosity of resin and varying pressures. Density of jute fabric used for permeability calculation in the jute-polyester study was 1.46g/cm3 and in the jute-corn syrup study was 1.38 g/cm3.

Composite Fabrication and Mechanical Properties Evaluation

Composites plates (460mm in width, and 310mm in length) were fabricated from both type of jute fabrics using polyester resin cured at 80 °C for 14 hours (with an initial drying of preforms for 2 hours at 80 °C).The specimens were prepared with dimensions of 300mm in length, 25mm in width and 3mm in thickness. The fibre volume fractions (V_f) were calculated as approximately 21.1% for the natural jute composite specimens and 23.0% for the bleached one. Tensile test of the composites at span length 150 mm and cross head speed of 2 mm/min were carried out using tensile testing machine Zwick 1474.

RESULTS AND DISCUSSION

Permeability Study

Table 1 shows the results of the permeability study. Comparing the infusion data of tests 2 and 3 as well as tests 4 and 5, it is observed that permeability of natural jute fabrics was higher than that of bleached jute fabrics. At constant pressure, permeability decreased with increasing viscosity of resin in both natural and bleached fabrics. The reason of higher permeability of natural jute than that of bleached one may be due to the differences in the macro/micro flow induced by capillary action, resultant effects of viscosity and capillary action and difference in architecture of fabrics i.e., the number of yarns in the warp direction of bleached jute reinforced composites is little greater than that of natural one in the present case. It is reported that capillaries of fibers contract due to bleaching treatment [2]. We expect a comparatively irregular geometry of fibers due to the contraction of fibers diameter (or collapsing of tubular structure of fibers) during bleaching treatment which could reduce the capillary pressure [1] resulting in lower permeability in case of said fibers. It was also observed that the bleached fibers were also contaminated with some press finishing agents like starch. As the fabrics were used as such without washing, it is believed that the press finishing materials in bleached fabrics might have interfered in the flow of the fluid resulting in lower permeability in the said fabrics. Infiltration through injection was carried out at two injection pressures keeping the viscosity constant. In this case also natural jute fabrics achieved higher permeability than bleached jute fabrics at both the injection pressures. However, a different trend is observed for natural and bleached fabrics at two different injection pressures. It may be due to difference in capillary pressures at different injection pressures. Permeability values at injection experiments disagree with that at infusion experiments. Since the permeability proved not to depend on the injection pressure [3], the larger the capillary pressure is, the more misled the calculation of K will be because the capillary pressure is not taken into account in the equation. From Fig. 1 it is observed that permeability of natural jute fabrics was higher than bleached jute fabric when corn syrup was used as fluid. Permeability decreased with increasing volume fraction of fabrics (Fig. 1). Changing the number of layers of fabrics during the experiment changed the volume fraction of preforms.

Mechanical Properties of Composites

Table 2 shows mechanical properties of both natural and bleached reinforced composites. Maximum stress, young’s modulus and strain at break is considerably higher in bleached jute composites as compared natural jute composites owing to the stronger fiber-matrix interfacial adhesion resulted due to bleaching treatment. Bleaching treatment improves hydrophobicity of fibers through delignification. This improved hydrophobicity makes the fiber more compatible with the polymer matrix leading to a better interface. The SEM micrographs of tensile fractured surface of composites (Fig. 2) corroborate this result. A large number of long pulled out fibers are observed in the micrograph of natural jute composites (Fig. 2a) which proves a weaker interface in case of untreated jute composites. However, a fewer number of short fiber pulled outs, transverse fiber breakages are observed in the micrographs (Fig. 2b) of bleached jute composites indicating a good fiber-matrix adhesion in the bleached jute composites.

Table 1 Infiltration results of jute fabrics with unsaturated polyester

Infusion				
No. of tests	Type of fabrics	Permeability (m2)	Viscosity (Pa.s)	Pressure (Pa)
1	Bleached	3.2E-11	0.08	5000
2	Bleached	3.1E-11	0.072	5000
3	Natural	4.6E-11	0.072	5000
4	Natural	3.0E-13	0.094	5000
5	Bleached	1.1E-13	0.085	5000
Injection				
1	Bleached	4.0E-11	0.11	3015
2	Natural	9.3E-11	0.11	3015
3	Bleached	6.3E-11	0.11	1160
4	Natural	8.7E-11	0.11	1160

Table 2 Mechanical properties of jute - polyester composites

Properties of composites	Natural	Bleached
Young modulus (MPa)	3533	4641
Maximum stress (MPa)	28.10	53.64
Strain at Break (%)	1.02	1.73

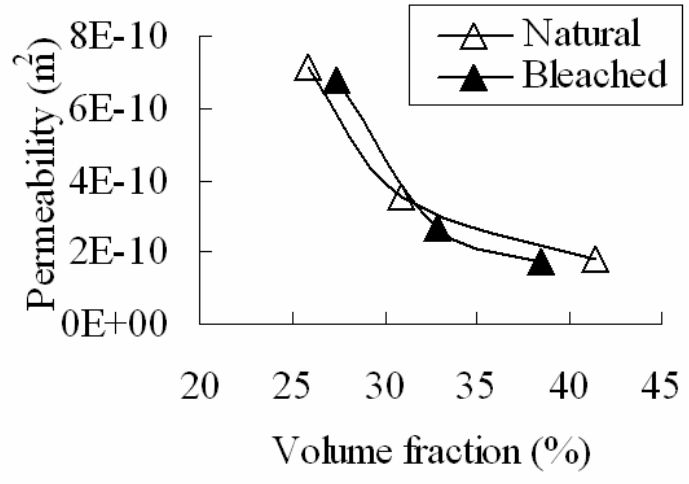
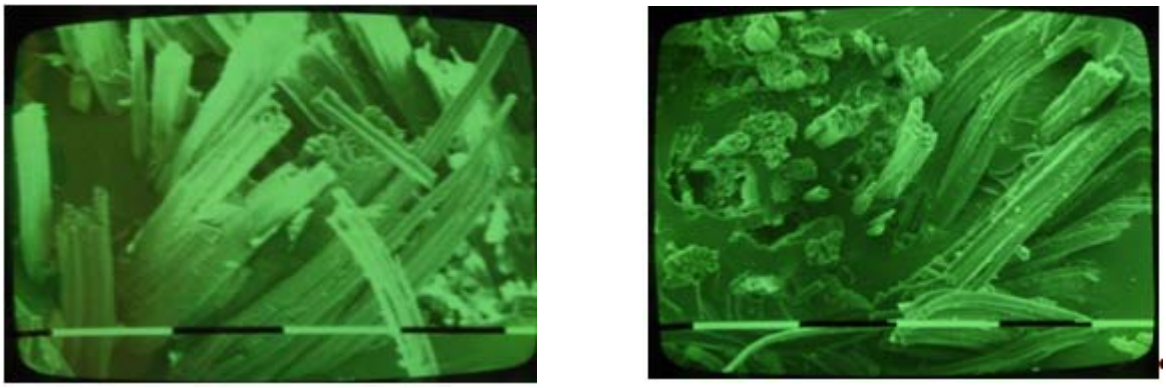


Fig. 1 Effect of fiber volume fraction (%) on permeability of jute fabrics (using corn syrup).



a) b)

Fig. 2 SEM pictures of tensile fractured surface of composites, a) natural: b) bleached.

CONCLUSION

Permeability study was carried out using woven natural and bleached jute fabrics. Rectilinear infiltration experiments were done with and without pressure. Unsaturated polyester and corn syrup in water were used as fluids in the investigation. Permeability of natural jute fabrics was higher than that of the bleached fabrics. Permeability of both natural and bleached preforms varied widely may be due to the some micro and macro flows related to the capillary action, presence of some press finishing materials on the bleached fabrics and different architecture of fabrics. Permeability of fabrics decreased with increasing volume fraction of fibers in preforms in both type of fabrics. Tensile test of jute-reinforced composites were carried out. Bleached jute composites achieved better tensile properties owing to the greater interfacial adhesion.

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