A COMPARATIVE STUDY ON THERMOSETTING BIOCOMPOSITES

Saswata Sahoo1*, Hiroyuki Hamada2*, Asami Nakai3*
*** Division of advanced fibro-science, Kyoto Institute of Technology, Matsugasaki, Sakyo, Kyoto, Japan 606-8585**

Keywords: *Epoxy, Polyester, Jute, Hygrothermal, Bleached*

Abstract

Biocomposites are emerging as solutions to the existing environmental issues. In the present investigation Composites were prepared from natural (unmodified) and modified (bleached & alkali treated) jute fabrics using hand lay-up technique. The effect of chemical modification and effect of fiber loading on the mechanical, hygrothermal, water absorption properties and surface morphologies were studied. The evaluated properties were compared. Better compatibility of jute with epoxy than polyester matrix was observed from the investigation. The tensile strength of natural jute-epoxy composites was 62.2MPa and natural jute polyester was 41.8 MPa. Flexural strength of natural jute-epoxy composite was 87.8 MPa that of polyester was 60.27MPa. Chemical treatment of fabrics improved the mechanical, hygrothermal and water absorption properties of resulting composites irrespective of resin matrix. Bleached jute –epoxy composites showed maximum flexural strength 109.9 MPa. A good co-relation between surface morphology and mechanical properties of composites was derived by scanning electron microscopy.

1 Introduction)

Natural fiber composites can provide adequate properties at a relatively low cost. The advantages of natural fibers over traditional man made glass fibers are: low cost, low density, low toughness, acceptable specific strength and biodegradability. Jute is one of the most common agro fibers which obtain good physico-mechanical properties suitable for effective reinforcement for polymer composites. However, the potential of jute in such application has remained largely unrealized in view of its poor wettability and adhesion characteristics towards many synthetic resins resulting in composites of poor strength and less than satisfactory environmental resistance. The poor mechanical performance of jute based composites is basically due to the high lignin and hemicellulose contents, hydrophilic nature of jute fiber and their moisture content (3-13%). Mechanical and hygrothermal properties of jute reinforced composites can be improved by modifying the fiber surface physically or chemically. The chemical surface modification of pineapple leaf fiber [1], coir [2], and sisal [3] and on performance of resulting polyester composites using hand lay up technique were investigated. They explained the effect of mercerization, bleaching, vinyl grafting, cyanoethylation and acetylation on the performance of composites. The mechanical, thermal, weathering properties and fracture surface morphology jute reinforced polyester composites were studied by Dash et al. [4-6]. Tripathy et al [7] studied the effect of surface treatment of jute on the interfacial strength with an epoxy resin. They reported the effect of surface treatment (bleached, mercerization) on the interfacial strength of composites.

2 Experimental

2.1 Materials

- The Bidirectional woven jute fabrics were collected from Sonali Aansh Industries Ltd. Comilla, Bangladesh.
  Natural (6lbs/2ply, 1.05 kg / mt)
  Bleached (6lbs/2ply, 0.92 kg/mt)
- Sodium hydroxide is collected from Nacalai Tesque Inc., Kyoto, Japan
- Unsaturated polyester resin (150 HRBQTNA), MEKP (hardener) were obtained from Showa Koubunnshi Chemicals Co. Ltd, Japan.
- Epoxy resin (Ef2f), hardener (YH300) and accelerator (EMY24) obtained from Japan Epoxy Resin Co. ltd

2.2 Surface Treatment of Fabrics

- The untreated (natural) jute fabrics were used as such without any washing for natural jute-composites.

- Mercerization: The untreated fabrics were immersed in 5% solution of sodium hydroxide for 2hr at 28-30ºC, then washed thoroughly with distilled water then air dried and finally dried in vacuum oven. These fabrics were designated as alkali treated fabrics.
- Bleaching: Bleached fabrics were supplied originally from the company.

2.3 Composite Fabrications

Bidirectional woven untreated and chemically modified jute fabrics (10" x 10") were oven dried for 4h at 100 ^{0}C under vacuum, then fabricated on an open steel mold using hand lay up method. The specimens were cured at room temperature for 24h and post cured for 2h at 100 ^{0}C in case of polyester and cured for 3h at 80 ^{0}C and post cured for6h at 120 ^{0}C in case of epoxy composites. The thickness of specimen maintained between 1.3-1.5mm using aluminum spacers. The test specimens of required dimension cut from the laminates and used for various testing.

2.4 Characterization of Composites

- Both tensile (specimen dimension 200 mm × 25mm × 1.5mm) and three point flexural tests(15mm width, 1.5mm thickness) of the composite specimen were carried out at 23ºC and 76% RH using Instron Universal Testing Machine (type 4206), at a crosshead speed of 1mm/min, span length100mm for tensile and gage length 28mm for flexural tests.
- The drop weight impact test of specimens was carried out by Instron Dynatup 9250HV (90mm×90mm)
- SEM photographs of tensile fractured surfaces of composite samples were recorded using JEOL JSM-5200 scanning electron microscope.
- Hygrothermal aging through immersion in hot water at 80^{0}C (200mm×25mm×~1.5 mm) for several hours.
- Water absorption test by immersion in cold water for 24h. (76mm × 15mm × 1.5mm rectangular bar conditioned at 90 ^{0}C for 24h)

  % water absorption $=W_1-W_0 / W_0 \times 100$ (1)

  % soluble matter lost$= W_0-W_2 / W_0 \times 100$ (2)

  (W_0=Conditioned weight, W_1 = Wet weight, W_2 = Reconditioned Weight)

3 Results and Discussion

3.1 Mechanical Properties

Effect of resin and chemical treatment on mechanical properties of composites is shown in table 1, 2. From table 1 it is observed that natural jute-epoxy composite has maximum tensile strength 62.2 MPa. Decrease of tensile modulus and tensile strength (about 29% in bleached jute-epoxy and 33% in case of alkali treated jute-epoxy) composites are noticed. A similar effect is noticed in case of polyester composites also. Alkali treated jute-epoxy composites has lesser tensile strength (TS) but almost similar tensile modulus(TM) than that having bleached jute. In case of polyester composites alkali treated jute gives better tensile property to the composites than bleached jute. Epoxy composites exhibit better tensile properties than polyester in case of both untreated / treated jute reinforcement. The decrease of tensile properties may attribute to the decrease of individual fiber strength due to chemical surface modification. The flexural strength and flexural modulus of both epoxy and polyester composites increased on chemical modification (both bleaching and alkali treatment). Bleached jute composites (both epoxy and polyester) show maximum flexural strength (FS) (increase of 25.2% and15.4% respectively than natural counterpart) and flexural modulus (FM) among all epoxy and polyester composites respectively. Epoxy composites exhibit better flexural properties than polyester composites. The increase in FS due to chemical modification of fiber may attributes to the formation of more flexible, less stiffness of fiber and greater fiber-matrix adhesion. From the impact properties (Table2), it is observed that alkali treatment of fabrics improved and bleaching decreased the impact performance of composites. The impact performance of polyester composites is comparatively better than epoxy composites. It may be due to the more brittle character of epoxy composites. The removal of lignin during bleaching treatment makes the fiber weak, which in turn resulted in less toughness of composites. The impact performance of composites depends upon fiber aspect ratio, fiber-matrix adhesion, nature of polymer material and stiffness of material.

3.1 Hygrothermal Properties

From Fig. 1 it is observed that % decrease of tensile strength is more in case of epoxy composites than the corresponding polyester composites. In case of natural jute composites, 36% decrease is observed in epoxy at182h ($\sqrt{T}$=13.49h) where as about 25% is observed in polyester composites. At 588h ($\sqrt{T}$=24.2) decrease of tensile strength is 53.3% and 50.5 % respectively for epoxy and polyester composites respectively. Similar trend is observed in case of surface treated jute composites. Surface

Table 1 Effect of chemical treatment and resin matrix on the tensile and flexural properties of composites

Jute Compos it--es	Tensile Strength (Mpa)	Tensile Modulus (Gpa)	Flexural Strength (Mpa)	Flexural Modulus (Gpa)
Polyester				
Natural	40.76	6.44	60.27	4.16
Bleached	30.15	5.65	69.55	5.51
Alkali treated	33.75	6.01	61.23	4.95
Epoxy				
Natural	62.2	7.13	91.72	4.85
Bleached	44.24	6.71	113.22	5.83
Alkali treated	41.94	6.91	99.39	5.04

Table 2 Impact properties of composites

Jute Compo-sites	NTT Total Energy (J/m)	Energy to Max Load (J)	Total energy absorbed (J)	Max Load (KN)
Polyester				
Natural	1.55	0.41	1.92	0.237
Bleached	1.29	0.36	1.77	0.142
Alkali treated	1.3	0.56	2.16	0.247
Epoxy				
Natural	1.23	0.14	1.55	143
Bleached	0.86	1.01	1.25	139
Alkali treated	1.29	1.6	2.04	0.2

treated jute-polyester composites showed less hygrothermal degradation (about 30-50% less) than the natural jute composites. Alkali treated jute composites are comparatively more stable to degradation than bleached jute composites except in case of polyester composites at 588h.

Water Absorption of Composites

3.3.1 Hot Water absorption

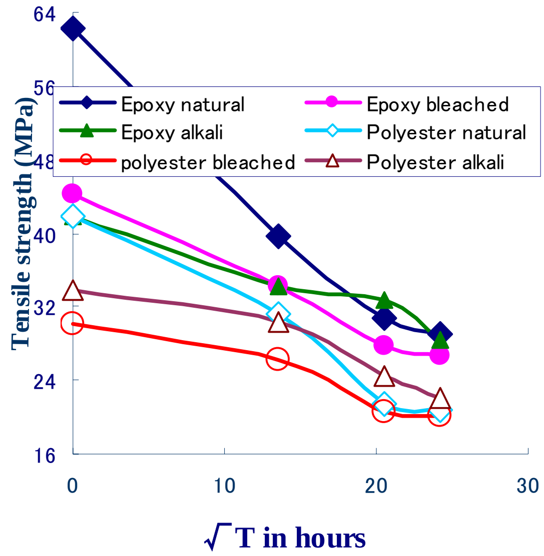

Fig. 1 Decrease of tensile strength with immersion time

From Fig. 2, it is observed that the trend of water absorption of composites depends upon time of immersion, nature of polymer and types of chemical treatments. Below 100h, epoxy composites showed less percentage of water absorption than the corresponding polyester composites. After 100h water absorption of epoxy composites increased dramatically than the polyester composites of both treated and untreated jute composites. The decrease of water absorption percentage in case of surface treated jute composites may be due to the improved fiber- matrix adhesion and improved hydrophobicity of fibers. Surface treatment improved hydrophobicity which might be caused due to removal of lignin and dissolution of hemicelluloses and other components of the jute fabrics. Removal of lignin and hemicelluloses results in the decrease of active hydroxyl group and increase of surface area for wetting of fiber with resin matrix.

3.3.2 Cold Water absorption

24h water absorption percentage and percentage of soluble matter lost of composites are shown in Fig.3. It is clear that epoxy composites have less water absorption than polyester composites. Chemical treatment reduced % water absorption as well as soluble matter lost. It attributes to the more fiber-matrix adhesion in surface treated jute composites.

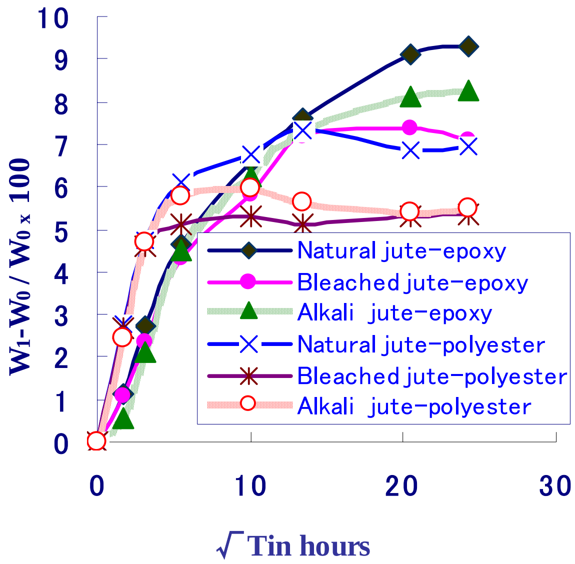

Fig. 2 Water absorption of composites with immersion time

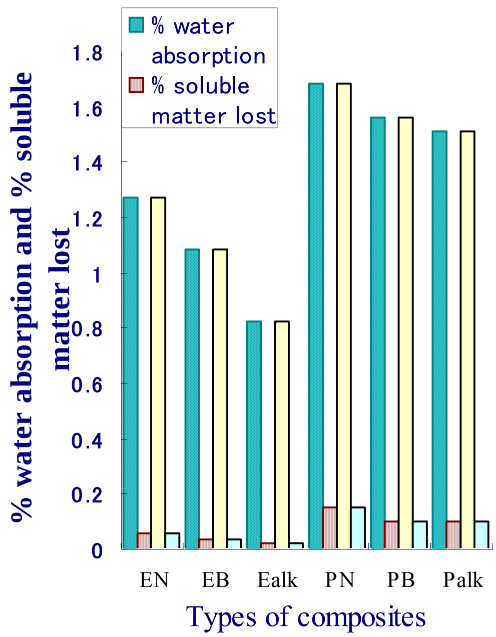

Fig. 3 24h Water absorption of composites

3.4 SEM Analysis

Fig. 4 shows the fracture surface morphology of natural jute polyester composite indicating clean fiber pullouts and large number of holes in the surface which proves a poor adhesion of natural fiber with resin matrix. In Fig. 5 fiber splitting due to bleaching and comparatively better fiber matrix adhesion is observed. In Fig.8, a better fiber- matrix adhesion is observed in alkali treated jute-polyester composite from matrix cracking and transverse fiber breakage of composites and fibers are tightly adhered to resin matrix. In Fig. 7, better dispersion of bleached fiber in epoxy resin is observed with lots of matrix coating on broken surface. It proves a greater fiber matrix adhesion due to surface treatment of fiber. Fig. 8 and 9 represent SEM micrographs of tensile fracture surfaces of natural and alkali treated jute polyester composites after 588h hot water immersion. Bunch of fiber pullouts in natural jute composite proves the poor interface in it. Fibers are very strongly adhered to resin matrix even after 588h water immersion at 80 ^{0}C in case of alkali treated-polyester composites, which proves the better adhesion and improved resistance of surface treated (alkali treated) composites to the hygrothermal degradation

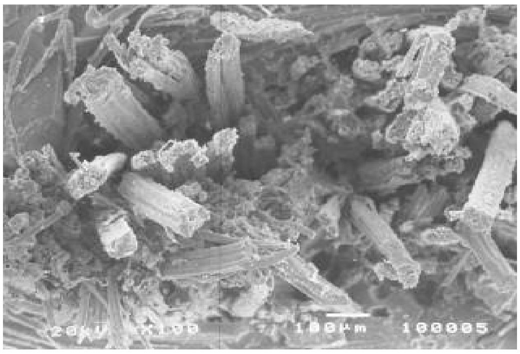

Fig. 4 SEM micrograph of tensile fractured surface of Natural jute-polyester composites

Fig. 5 SEM micrograph of tensile fractured surface of bleached jute polyester composites

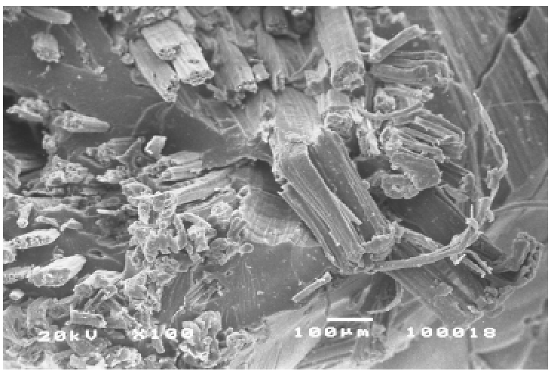

Fig. 6 SEM micrograph of tensile fractured surface of alkali treated jute polyester composites

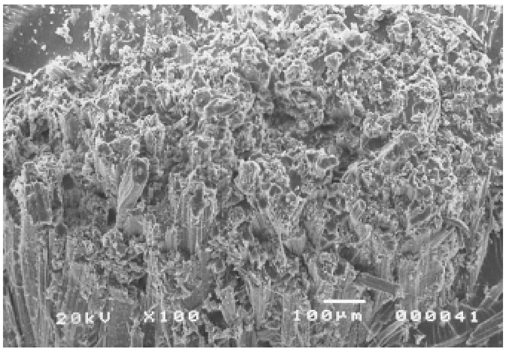

Fig. 7 SEM micrograph of tensile fractured surface of alkali treated jute epoxy composites

4 Conclusions

Improvement in mechanical and hygrothermal behavior were obtained with the use of surface treated fabrics. Both treated and untreated fabrics are compatible to epoxy resin more than that of unsaturated polyester. Bleaching treatment improved flexural strength of composites. Alkali treatment proved beneficial towards hygrothermal properties of composites.

5 Acknowledgements

Authors are grateful to the Venture Laboratory of Kyoto Institute of Technology for providing financial support for this research work.

6 References

[1] Mishra S., Misra M., Tripathy S.S., Nayak S. K. and Mohanty A. K., "Potentiality of pineapple leaf fiber as reinforcement in PALF-polyester composites: surface modification and mechanical properties." J. Reinf. Plast. Compos., Vol. 20 No. 4, 321, 2001

[2] Rout J., Misra M., Tripathy S. S., Nayak S. K. and Mohanty A. K., "The influence of fibre surface modification on the mechanical properties of coir polyester composites." Polym. Compos., Vol. 22,468, 2001

[3] Mishra S., Misra M.,. Tripathy S. S., Nayak S. K. and Mohanty A. K., "The influence of chemical surface modification on the performance of sisal polyester biocomposites." Polym Compos., Vol. 23, No. 2, 164, 2002.

[4] Dash B. N., Rana A. K., Misra H. K., Nayak S. K and Tripathy S. S., "Novel Low-cost jute-polyester composites, part-I: processing, mechanical properties and SEM analysis." polym. Compos., Vol. 20, 62, 1999.

[5] Dash B. N., Rana A K., Misra H. K, Nayak S. K. and. Tripathy S. S, Novel Low-cost jute-polyester composites II: SEM observation of the fractured surfaces". Polym.-Plast. Eng., Vol. 39, 33, 2000.

[6] Dash B. N., Rana A. K., Misra H. K., Nayak S. K. and Tripathy S. S., Novel Low-cost jute-polyester composites, III: Weathering and Thermal behavior." J. Appl. Polym. Sci., Vol. 78, 1671, 2000.

[7] Tripathy S. S., Landro L. D., Fontanelli D., Marchetti A. and Levita G.," Mechanical properties of jute fibers and interface strength with an epoxy resin". J. Appl. Polym. Sci., Vol. 75, 1585, 2000.

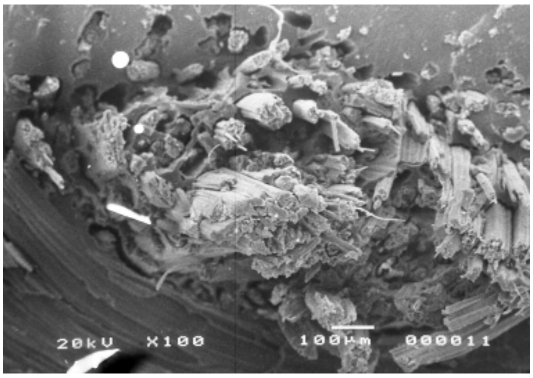

Fig. 8 SEM micrograph of tensile fractured surface of natural jute-polyester composites after 588h of hot water immersion

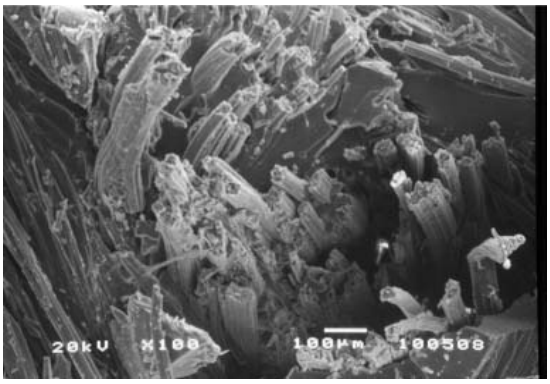

Fig. 9 SEM micrograph of tensile fractured surface of alkali treated jute polyester composites after 588h hot water immersion