J. Inst. Eng. India Ser. D (January–June 2016) 97(1):55–58
DOI 10.1007/s40033-015-0073-9

ORIGINAL CONTRIBUTION

Surface Resistance of Jute Fibre/Polylactic Acid Biocomposite to Wet Heat

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Received: 19 February 2015 / Accepted: 6 April 2015 / Published online: 1 May 2015

Abstract Jute fibre/polylactic acid (PLA) composite is of special interest because both resin and reinforcement come from renewable resources. Thus, it could be a more eco-friendly alternative to glass fibre composite [1] and to conventional wood-based panels made with phenol–formaldehyde resin which present many drawbacks for the workers and the environment [2]. Yet the water affinity of the natural fibres, the susceptibility of PLA towards hydrolysis and the low glass transition of the PLA raise a question about the surface resistance of such composites to wet heat in service condition for a furniture application [3]. In this work, the surface resistance of PLA/jute composite alone and with two different varnishes are investigated in regard to an interior application following the standard test method in accordance to BS EN 18721:2009: "Furniture: assessment of surface resistance to wet heat". It is compared to two common wood based panels, plywood and hardboard. After test, the composite material surface is found to be more affected than plywood and hardboard, but it becomes resistant to wet heat when a layer of biosourced varnish or petrol-based polyurethane varnish are applied on the surface.

Keywords Surface resistance · Wet-heat · Polylactic acid · Jute · Biocomposite

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Introduction

Increases of crude oil prices and environmental awareness have aroused interests in green products in the past years. Natural fibres have proved to be an efficient reinforcement for composites and a good substitute for glass fibre, giving high specific strength and reducing weight, cost and carbon footprint [1].

These jute/polylactic acid (PLA) biocomposites could be eco-friendly alternative to the wood-based panels (WBP). WBP are made of wood fibres or wood veneer and phenol–formaldehyde resin. This resin presents many drawbacks for the workers and the environment, emitting toxic emission and known to be carcinogenic at a certain level [2]. WBP are commonly used for interior furniture application and the jute/PLA composite could find the same application, but the last one must present the same resistance to a daily use, without lost of aesthetic. Yet the water affinity of the fibres [3] and the high sensitivity to moisture and temperature (above 40 °C) of the PLA [4] raise the question of the surface resistance of the composite to hot liquid. Jute fibre, as a lignocellulosic fibre, is hydrophilic and tends to absorb moisture [5]. Moisture penetration into composite occurs by capillary transport by the fibre into the gaps and flaws at the interfaces between fibres and polymer [3]. If the material is not resistant enough, improvement can be brought by adding a layer of varnish on the surface. It has been chosen to use common polyurethane for its affinity with cellulosic material such as wood and for its ability to resist outdoor ageing [6]. Synthetic resins are particularly notable for their hardness and durability and their high degree of resistance to the action of water [7]. A bio-based varnish made from succinic acid, Bio-SA^{TM}, will also be tested. This varnish is obtained by catalysation of biosourced succinic acid made by

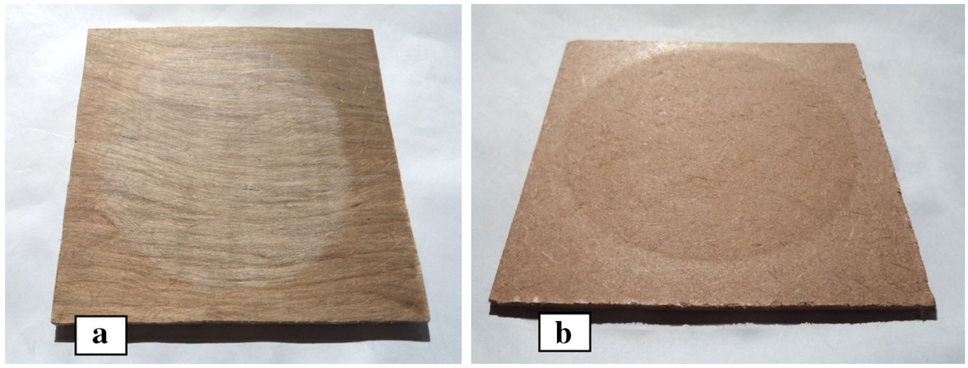

Fig. 1 Shows samples after surface test: **a** is the jute/PLA biocomposite sample without varnish, **b** is the hardboard sample

fermentation of fructose corn syrup [8]. Thus it is a more eco-friendly varnish made using renewable feedstock [8].

BS EN 18721:2009: "Furniture: assessment of surface resistance to wet heat" for all rigid furniture surfaces appears the most relevant standard because of the possibility of degradation by heat and humidity of the composite and the test is made in comparison with two WBP, plywood and hardboard.

Material and Method

Jute fibres were provided by Gloster Jute Mills Ltd, Kolkata. The PLA Earthfirst TCL was bought from Sidaplast Ltd, Belgium. The sodium hydroxide was purchased from Industrial and Chemical Concern, Kolkata. Most common Plywood grade A-D for interior application and hardboard common grade AA were purchased from Green-Ply Ltd Company, Kolkata. The Bio-SA^{TM} resin was procured from BioAmber Company, Canada. The polyurethane varnish was from Sakshi Dyes & Chemicals, India.

The Jute/PLA composite samples were prepared with 60 % fibres. The fibres were treated with sodium hydroxide (NaOH) to reduce moisture sensitivity by strong bonding of the cell wall polymers in the fibre with the matrix [9]. Jute fibres were immersed for 2 h in 2 % NaOH solution, rinsed, dried for 2 days outside and then dried in an oven at 140 °C for 3 h. Then layers of matrix and fibres were alternately stacked in a mould and compression moulded at 180 °C and 200 kg/cm^2 pressure, to form a board of 5 mm thickness. The boards were then cut into pieces of 120 × 120 × 5 mm dimension. The plywood and hardboard were cut in the same dimensions.

One piece of biocomposite was covered with a layer of Bio-SA^{TM} resin and another with a layer of polyurethane and was then left to dry for 2 weeks.

As specified in BS EN 12721:2009, an aluminium alloy block was heated to 90 °C and was placed on a damp polyester cloth in contact with the test surface. After 20 min, it was removed and the surface was left for 16–24 h to dry. Thereafter, the surface was cleaned and visually examined for damages such as discolouration, change in gloss, colour, blistering and swelling. The test result is stated with number from 1 to 5 as described in BS EN 12721:2009.

Discussion

The treated Jute/PLA composite without varnish (Fig. 1a) was affected by the test at level 3 on a total of 5 as described in BS EN 12721:2009 which was a moderate change: test area was distinguishable from adjacent surrounding area e.g. visible discolouration, change in gloss and colour. There were no distinct changes in the surface structure, e.g. swelling, fibre raising, cracking, blistering. Even if this change would have been acceptable for structural parts of furniture which were exposed to hot liquid, it was not satisfying the requirement for a table surface as example and standard tests with protective varnish layer were pursued.

The PLA composite's surface degradation was more important than the hardboard's one (Fig. 1b) which exhibits minor change, 4 on 5: test area was distinguishable from adjacent surrounding area, only when light source was mirrored on the test surface and was reflected towards the observer's eye, e.g. discoloration, change in gloss and colour.

The plywood in Fig. 2 didn't exhibit any visible changes, (5 on 5). Plywood was made of wood veneers mainly composed of cellulosic fibres as well as jute fibres [9]; yet they were not embedded in the added resin. The more visible changes on the surface for the biocomposite indicate that the PLA resin has an important part to play in the change of surface of the biocomposite.

It has been seen on the initial material (Fig. 3a), that the fibres are well embedded with the PLA. In Fig. 3b, it can be seen that the fibres were pulled out of the surface after the test and the PLA layer was removed at places. PLA has a low glass transition temperature and a first deflection point around 60 °C [10]. As the test was performed at 90 °C, it means that the PLA softens at this temperature and it was evident from the SEM view that it was debonded

Fig. 2 Shows a plywood sample after test and it is not damaged

from the fibres on the surface. Furthermore, discolouration or lightening of the surface indicates an opacification and crystallisation of the PLA occurring with hydrolysis and degradation of the PLA [3]. Another process involved in the surface degradation was the water absorption by the surface exposed fibres after the PLA matrix was softened. The fibres being exposed on the surface can absorb more water from the environment, initiated by fibre capillarity [11]. On absorbing water, the fibre diameter expands, debonding the fibre even more from the matrix. Therefore, adding a protective layer of a resin which is not sensitive to moisture and heat, such as polyurethane or a biosourced varnish, would act as a moisture barrier coating [9] and improve the surface resistance.

The BS EN 12721 test was conducted again with the material covered with a layer of bio- Bio-SA™ and a common polyurethane varnish from Sakshi Dyes & Chemicals.

It appears that both resins bring significant protection and reach 4–5 on 5 levels as described in BS EN 12721:2009, no changes to minor changes (Fig. 4); test area is distinguishable from adjacent surrounding area, only when light source is mirrored on the test surface and is reflected towards the observer's eye. Visual inspection suggests that the biosourced varnish shows similar extent of surface resistance as provided by the synthetic polyurethane varnish.

It can be seen in Fig. 5 that the varnished surface are shinier than without varnish and the fibres have not been pulled out after test (b). There is also not much visible difference between before (a) and after test (b).

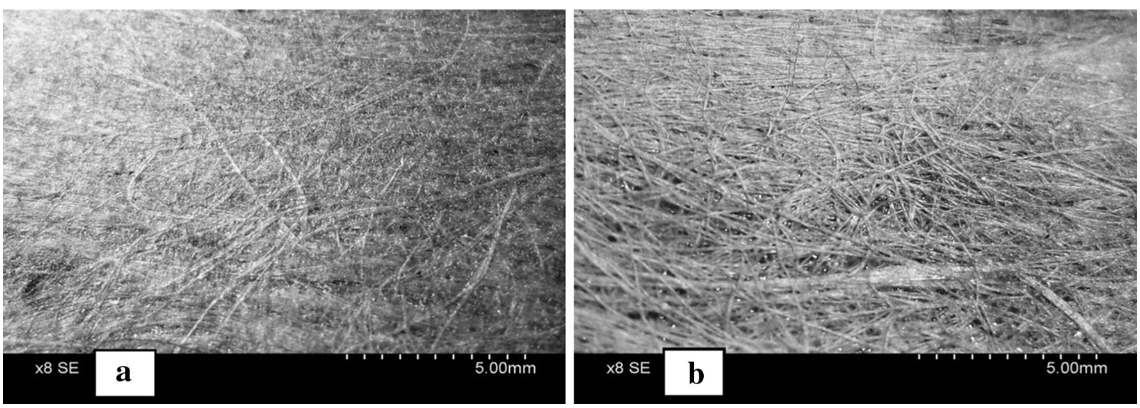

Fig. 3 SEM views of the biocomposite material surface; **a** the surface untouched by the aluminium block, **b** the damaged surface after test

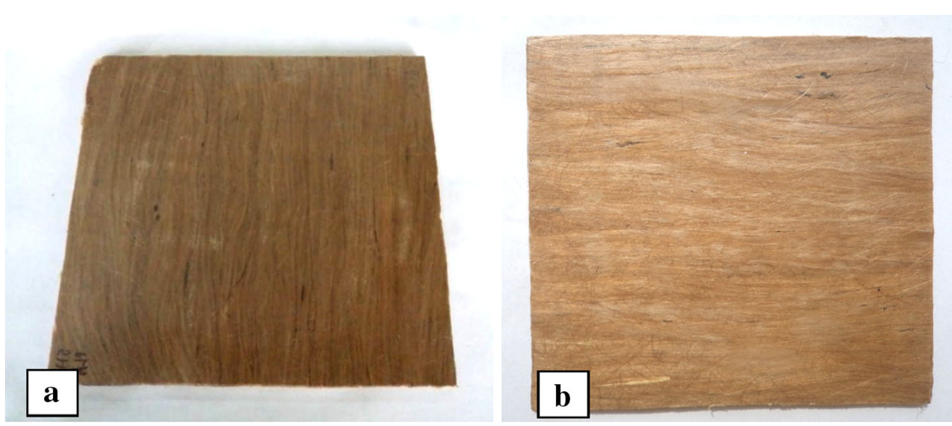

Fig. 4 Shows a sample with Bio-SA™ resin (**a**) and a common polyurethane (**b**), after test

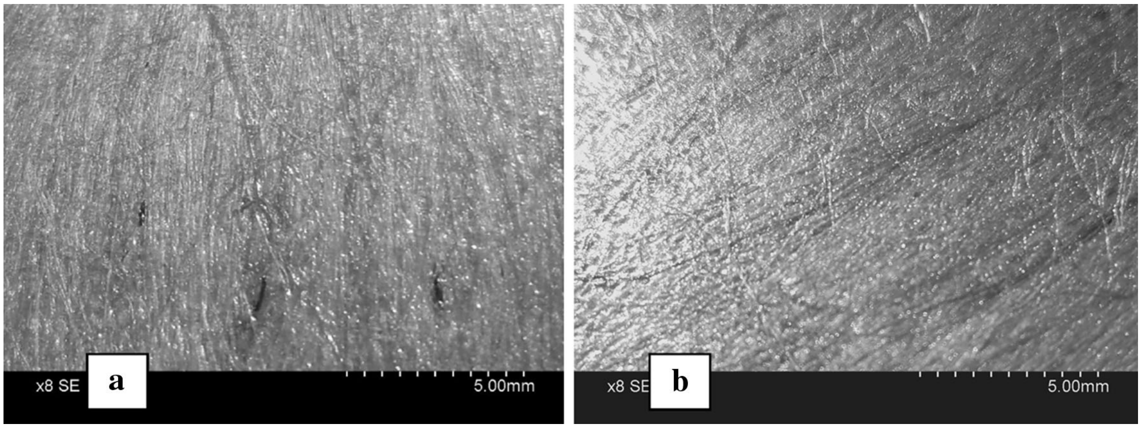

Fig. 5 Shows the composite surface with the biosourced Bio-SA^{TM} varnish, **a** before test and **b** after test

Conclusion

The PLA/jute composite surface without varnish was affected at a moderate level by the wet heat treatment done in accordance with BS EN 18721:2009: "Furniture: assessment of surface resistance to wet heat". Both PLA degradation and water absorption by jute fibres were responsible for this visible damage. This moderate level of surface resistance would be acceptable for structural parts of furniture which are not likely to support hot liquid. Yet it is not acceptable for application likely to support hot liquid such as a table surface as example. Applying a layer of biosourced succinic acid based varnish or a layer of common polyurethane varnish helps reaching the 4–5 on 5 level of resistance to wet heat of the BS EN 18721:2009 standard. Further, surface resistance tests to oil, surfactants or chemicals would be the next step to assess the complete surface resistance of the jute/PLA composite for an interior furniture application.

References

1. S.V. Joshia, L.T. Drzalb, A.K. Mohanty, S. Arorac, Are natural fiber composites environmentally superior to glass fiber reinforced composites? Composites **35**, 371–376 (2003)
2. J.A. Youngquist, *Wood-based Composites and Panel Products, Review of the Environmental Impact of Wood Compared with Alternative Products Used in the Production of Furniture* (Forest and Wood Products Research and Development Corporation (FWPRDC), 2003), pp. 5–15
3. D.E. Henton et al., Polylactic acid technology. Nat. Fibers Biopolym. Biocompos. **1**, 540 (2005). (chap. 16.5.1.2)
4. C.P.L. Chow, X.S. Xing, R.K.Y. Li, Moisture absorption studies of sisal fibre reinforced polypropylene composites. Compos. Sci. Technol. **67**, 306–313 (2007)
5. A.C. Karmaker, Effect of water absorption on dimensional stability and impact energy of jute fibre reinforced polypropylene. J. Mater. Sci. Lett. **16**, 462–464 (1997)
6. J. Hua, X. Lib, J. Gaob, Q. Zhaob, Ageing behavior of acrylic polyurethane varnish coating in artificial weathering environments. Prog. Org. Coat. **65**(4), 504–509 (2009)
7. K.F. Lin, Paints, varnishes, and related products. Bailey's Ind. Oil Fat Prod. **6**, 9 (2005)
8. R. Luque, S. Carol, K. Lin, C. Du, J. Duncan, D.J. Macquarrie, A. Koutinas, R. Wang, C. Webb, J.H. Clark, Chemical transformations of succinic acid recovered from fermentation broths by a novel direct vacuum distillation-crystallisation method. Green Chem. **11**, 193–200 (2008)
9. B. Madsen, E. Gamstedt, *Wood versus plant fibers: similarities and differences in composite applications*. Advances in Materials Science and Engineering, vol 2013 (Department of Wind Energy, Technical University of Denmark, Denmark, 2013)
10. T.F. Cipriano et al., Thermal, rheological and morphological properties of poly (lactic acid) (PLA) and talc composites, Polímeros **24**, 3 (2014)
11. S. Karlsson, B.S. Ndazi, Characterization of hydrolytic degradation of polylactic acid/rice hulls composites in water at different temperatures. Res. J. Recent Sci. **1**(9), 54–58 (2012)