Fibers and Polymers 2012, Vol.13, No.7, 894-898 DOI 10.1007/s12221-012-0894-1

Flexural and Impact Properties of Chemically Treated Sugar Palm Fiber Reinforced High Impact Polystyrene Composites

D. Bachtiar[1]*, S. M. Sapuan[1], A. Khalina[2], E. S. Zainudin[1,3], and K. Z. M. Dahlan[4]

[1]*Department of Mechanical and Manufacturing Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[2]*Department of Biological and Agriculture Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[3]*Biocomposites Technology Laboratory, Institute Tropical Forestry and Forest Product (INTROP), Putra Infoport, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[4]*Radiation Processing Division, Malaysian Nuclear Agency, Bangi 40300, Kajang, Selangor, Malaysia*
(Received October 14, 2011; Revised January 14, 2012; Accepted February 11, 2012)

Abstract: The effects of chemical treatment on the flexural and impact properties of sugar palm fiber reinforced high impact polystyrene (HIPS) composites were studied. Two types of concentration of alkali solution (4 % and 6 %) and also two types of percentage of compatibilizing agent (2 % and 3 %) have been used in this study. The alkaline treatment is carried out by immersing the fibers in 4 % and 6 % of alkali solution for 1 hour. A 40 wt. % of alkali treated sugar palm fiber (SPF) was blended with HIPS using Brabender machine at temperature of 165 °C. The second treatment was employed by compounding mixture of sugar palm fibers and HIPS with 2 and 3 % of compatibilizing agent using the same procedure. The composites plate with dimensions of 150×150×3 mm was produced by using the hot press machine. The flexural strength, flexural modulus and impact strength of composites were measured and the values were compared to the untreated composites. Improvement of the mechanical properties of the composites has been shown successfully. Alkali treatment using 6 % NaOH solution improve the flexural strength, flexural modulus and impact strength of the composites as amount 12 %, 19 % and 34 % respectively, whereas compatibilizing agent treatment only showed the improvement on the impact strength, i.e. 6 % and 16 % improvement for 2 % and 3 % MAH respectively.

Keywords: Flexural properties, Sugar palm fiber, HIPS, Alkaline treatment, Impact strength

Introduction

Sugar palm or *Arenga pinnata* tree, a member of *Palmae* family, is a promising source of natural fiber. Geographical distribution of sugar palm covers the Indo-Malay archipelago and is spread in all of tropical Southeast Asia countries, from Myanmar to the Philippines. Indonesia and Malaysia forest also were rich by this plant naturally. The black fiber, or locally known as *ijuk*, was started to produce from the mature tree after 5 years. Figure 1 depicts the location of fiber on the sugar palm tree. Traditionally applications of this fiber have covered a wide range, including rope, brooms, paintbrushes, filters, doormats, chair/sofa cushions, and for roofing. Exploring opportunity of sugar palm fibers as reinforcing polymer composites material has become new alternative one because their good performances in traditional applications, like fiber's strength and durability [1].

Natural fiber reinforced polymer composites have been studied intensively as alternative to synthetic fibers (glass fiber especially) [2]. It is because polymer composites material reinforced by synthetic fibers had some environmental and health problems. The advantages that will appear when natural fibers were used over synthetic fiber are low density, biodegradability, healthy environmentally, easy of separation, easy availability, enhanced energy recovery, non-corrosive nature, low cost, good thermal and acoustic insulation properties [3]. Various types of natural fibers have been reported to be used as reinforcement in polymer composites, and these include hemp, flax, abaca, sisal, jute, henequen, kenaf, ramie, oil palm, pineapple leaf, banana pseudo-stem, sugarcane bagasse, coir, rice husk, wood, and bamboo [4,5].

Some early studies have been carried out as attempt to explore the capability of sugar palm fiber. Sastra *et al.* [6] studied the performance of sugar palm fiber reinforced epoxy composites and showing the good mechanical properties.

Figure 1. Sugar palm tree and location of the black sugar palm fiber.

*Corresponding author: dandibachtiar@gmail.com

One product has successfully been developed from sugar palm fiber composites [7]. The work presents the fabrication of hybrid unsaturated polyester composite boat made from sugar palm and glass fibers.

However, the main problem that was faced to develop composite from natural fiber is interfacial bonding between fiber and matrix. It is caused by the hydrophilic behaviour of fiber with high content of hydroxyl groups (OH) and hydrophobic matrix behavior produces the poor adhesion between them. Consequence, stress transfer cannot be full transferred when composites subjected to loading, and the strength of composites was not maximized. Some researchers everywhere usually carried out several treatments to solve this problem [8,9]. Some most methods usually used are alkali treatment, silane treatment, and graft copolymerization of monomer directly on the surface. Alkali treatment has been proved significantly improving the sugar palm fiber reinforced thermoset matrix polymer [10-12]. Their study showed the combination of parameters soaking time and solution concentration play a role to get optimum mechanical strength of the composites.

This research examined the effect of alkali treatment and compatibilizing agent on the mechanical performance of sugar palm fiber when was used to reinforcing the thermoplastic composites. High impact polystyrene (HIPS) was used as the thermoplastic composites material. High Impact Polystyrene (HIPS) is a type of polystyrene in which polybutadiene is added during polymerization. Polystyrene has known usage for high-quality goods, e.g. toys, household appliances, cases, boxes, and calculators, computer housings, and it suggested application in this research is for roof tile. The flexural and impact properties of SPF-HIPS composites were examined.

Materials and Method

Materials

The high impact polystyrene (HIPS) used as the polymer was Idemitsu PS HT 50 supplied by the Petrochemical (M) Sdn Bhd, Pasir Gudang, Johor, Malaysia. The sugar palm fiber (SPF) was obtained from Aceh, Indonesia. The fibers were crushed by pulverisette machine to be short form and sieved through 30 and 50 mesh screen. There are two types of treatment that were used in this study which are mercerization using the alkali solution and the polystyrene-block-poly(ethylene-ran-butylene)-block-poly(styrene-graft-maleic-anhydride), as compati-bilising agent. NaOH and compatibilizing agent materials were supplied by Aldrich Chemical Company, Malaysia.

Process of Treatments

Mercerization or alkali treatment was carried out by immersing the short fibers in NaOH solution with two type concentrations, 4 % and 6 % during 1 hour at room temperature. Fibers/solution ratio was 1:20 (w/v). Then, the fibers were cleaned by distilled water several times to ensure that the final condition of fibers were free from excess NaOH. On another treatment, two different weight concentrations (2 and 3 wt. %) of compatibilizing agent were applied by adding inside mixture of SPF and HIPS when compounding process was employed by Brabender machine.

Preparation of Composites

The sugar palm fibers (40 wt. %) were mixed into the HIPS matrix using a Brabender Plasticorder intensive mixer, model PL2000-6 at temperature 165 ^{o}C and rotor speed 50 rpm. The mixing process was performed in the following step. First, the HIPS (58 wt. % and 57 wt. %) and compatibilizing agent (2 wt. % and 3 wt. %) were premixed at room temperature for 3 minutes. Then, HIPS and compatibilizing agent was placed inside the mixing chamber for about 2 minutes, afterward the SPF was added inside the mixing chamber for 10 min. The total for mixing process was 12 minutes. Then the resulting material was compressed in the mould using hot press machine at temperature 165 ^{o}C, nevertheless it endured the process of pre-heating for 5 minutes and fully press-heating for 5 minutes. This was followed by cooling process for 5 minutes and the final result of the composites was formed into sheets. The same procedure also was applied for the alkali treated sugar palm fibers with mixing composition 40 wt. % alkali treated fiber and 60 wt. % HIPS matrix. The final products were in the form of plates with dimensions $150\times150\times3$ mm.

Flexural Test

Flexural test was carried out on an Instron Tensile model 5569 according ASTM D 790 standard. The support span length was set at 100 mm and the cross-head speed of testing at 5 mm/min. Test was performed using a load cell of 10 kN. The six identical samples of each composition were measured and the average values were reported. Flexural strength and flexural modulus were recorded.

Impact Test

The impact resistance of the composites were employed by Izod impact test. The notched samples of 63.5 (L)$\times$12.7 (W)$\times$3 mm (T) were used as specimen composites. The Izod impact strength was reported as energy per unit notch area (kJ/m^2). The pendulum energy employed for the testing purpose was 4 Joules and the tests were carried out according to ASTM D256 at Polymer Laboratory, Malaysian Nuclear Agency.

Morphology of Fracture Surfaces

Studies of the morphology of fracture surface of composites were carried out by using a Scanning Electron Microscopy (SEM) model Hitachi. SEM was used to examine qualitatively the dispersion of fibers in the HIPS matrix and to observe visually the interface fiber and matrix composites. All specimens were coated with a thin layer of gold to eliminate charging effects.

Results and Discussion

Flexural Properties

The effects of compatibilizing agent (2 % and 4 %) and alkali treatments (4 % and 6 %) of short sugar palm fibers on the flexural strength and flexural modulus of SPF-HIPS composites were examined using the 40 wt. % of fiber composites.

From Figure 2, it can be seen that the flexural strength of the composites with alkali treated were improved from the untreated composites. Unfortunately, when the treatment with compatibilizing agent was applied to composites, the results were shown no improvement yet. It may be the content of compatibilizing agent still not enough to influence the flexural characteristic of the composites. Whereas, the anhydride groups of the copolymers may react with the surface hydroxyl groups of natural fibers forming ester bonds whilst the other end of copolymer entangles with the polymer matrix due to their similar polarities [13]. From this study, it was seen that compatibilizing agent as amount 2 % and 3 % MAH giving no enhancement effect to flexural properties.

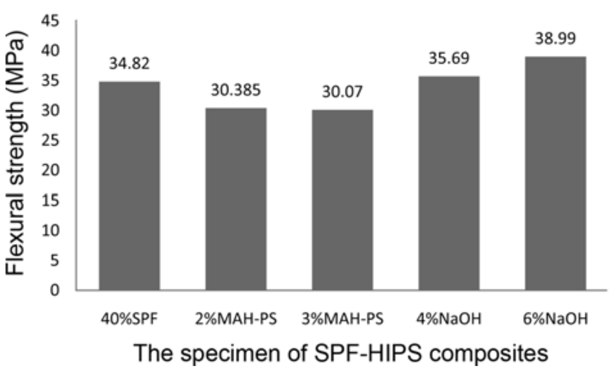

Figure 2. Flexural strength of untreated and treated of SPF-HIPS composites.

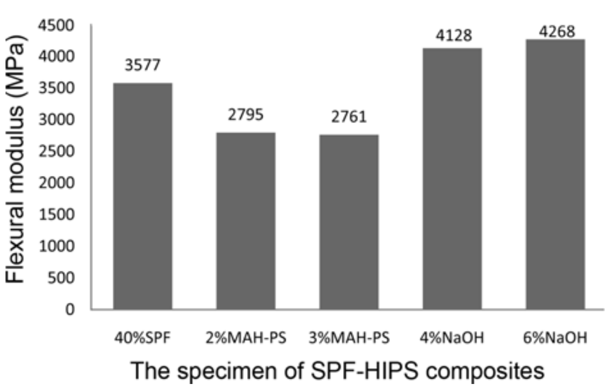

Figure 3. Flexural modulus of untreated and treated of SPF-HIPS composites.

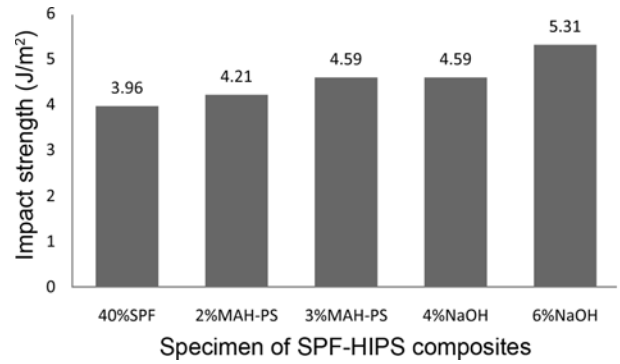

Figure 4. Impact strength of untreated and treated of SPF-HIPS composites.

Figure 3 also shows similar characteristics for the flexural modulus value of the composites. Flexural modulus of alkali treated composites higher than the untreated composites. The improvement value applies to both alkali treatment, and the highest one was shown by 6 % alkali treated. Meanwhile, adding compatibilizing agent shows decreasing value of flexural modulus. This is similar behaviour with the previous study that carried out by Chow and Ooi [14]. The anhydride groups may be lead to softly composites as the effect of chemical reaction in the composites.

Impact Strength

Figure 4 depicts the performance of impact strength of short sugar palm fiber/high impact polystyrene composites with alkali treatment and compatibilizing agent treatment. The improvement was shown for all the type of treatment. It was caused by development of rough surface fiber which offers good fiber-matrix adhesion as the effect of alkali treatment. Alkali treatment also removes the hemicelluloses and lignins part in fiber and remain the strength cellulose components on the fibers [15]. It was also attribute to get the higher impact strength of composites. The compatibilizing agent also could influence the impact strength due to chemical reaction of hydroxyl goups of fibers with the anhydrid groups of the copolymers lead to good interface adhesion fiber-matrix. Finally, it contributed to enhancement of impact strength of the composites.

SEM Analysis

SEM micrograph was used to investigate the qualitative assessment on fracture surface condition especially the interfacial adhesion phenomenon of fiber and matrix for the composites after subjected to impact testing. Figure 5 shows the fracture surface of untreated SPF-HIPS composites. It can be seen that the interface between fiber and matrix have poor bonding as indicated by the wide gap between them. Furthermore, the void also attributes to weak the strength

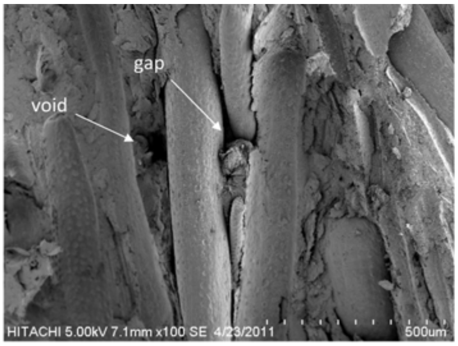

Figure 5. The impact fracture surface of untreated 40 %SPF-HIPS composites.

Figure 6. The fracture surface of SPF-HIPS composites with addition 2 %MAH.

Figure 7. The fracture surface of SPF-HIPS composites with addition 3 % MAH.

caused by imperfect mixing for untreated composites.

Figure 6 and 7 show the fracture surface of composites with 2 % and 3 % addition of MAH compatibilizing agent. It can be seen the good adhesion in interface of fiber and matrix that indicated by the thin gap between them. It was the effect of infiltration maleic anhydride on the HIPS matrix. The picture also depicts the breakage fiber that indicates good adhesion of fiber-matrix interface when subjected to impact loading. From Figure 6, it can be seen a sticking part of matrix on the fiber surface after impact loading, also shown the good adhesion as caused by infiltration of MAH.

Figure 8. The fracture surface of SPF-HIPS composites with 4 % alkali treated.

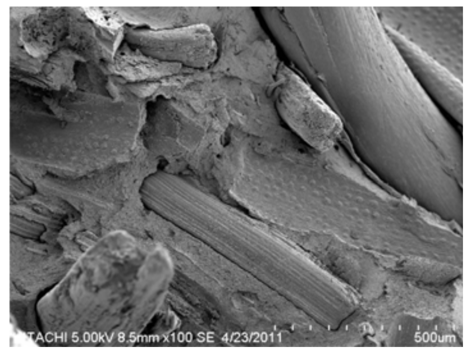

Figure 9. The fracture surface of SPF-HIPS composites with 6 % alkali treated.

Figure 8 and 9 show the fracture surface of composites with 4 % and 6 % alkali treated. From these photographs also are seen the roughness surface fiber as result alkali treatment. The roughness surface was resulted from abrasion of impurities on the fiber surfaces. This phenomenon also cause to improving the mechanical locking between the fiber surface and matrix. It was also attributed to higher impact strength of alkali treated composites than impact strength of composites with MAH addition.

Conclusion

The study of effect the chemical treatments on natural fiber composites tailoring from 40 wt. % sugar palm fiber and HIPS matrix has been done. Alkali treatment using 6 % NaOH solution could improve the flexural strength, flexural modulus and impact strength of the composites from the untreated composites as amount 12 %, 19 % and 34 % respectively. Compatibilizing agent namely polystyrene-block-poly(ethylene-ran-butylene)-block-poly(styrene-graft-maleic-anhydride) that was used in this study only showed the improvement on the impact strength, i.e. 6 % and 16 % improvement for 2 % and 3 % MAH respectively, meanwhile, no enhancement of the composites properties when subjected to flexural properties testing.

Acknowledgements

The authors wish to thank the assistance of Mr. Wildan Ilyas Mohamad Ghazali, Mr. Al Falah and Mr. Wan Ali in carrying out the experimental work and University Putra Malaysia for the financial assistance through a Graduate Research Fellowship for the principal author. The authors also would like to thank Ministry of Agriculture (Science Fund) in Malaysia for financial support.

References

1. J. Mogea, B. Seibert, and W. Smiths, *Agrofores. Sys.,* **13**, 111 (1991).
2. J. Biagiotti, D. Puglia, and J. M. Kenny, *J. Nat. Fiber.,* **1**, 37 (2004).
3. A. S. Singha and V. K. Thakur, *B. Mater. Sci.,* **31**, 791 (2008).
4. N. D. Saheb and J. P. Jog, *Adv. Polym. Tech.,* **18**, 351 (1999).
5. A. K. Mohanty, M. Misra, and L. T. Drzal, *J. Polym. Environ.,* **10**, 19 (2002).
6. H. Y. Sastra, J. P. Siregar, S. M. Sapuan, Z. Leman, and M. M. Hamdan, *Am. J. Appl. Sci.*, **Special Issue**, 21 (2005).
7. S. Misri, Z. Leman, S. M. Sapuan, and M. R. Ishak, *IOP Conf. Series: Mater. Sci. Eng.,* **11**, 012015 (2010).
8. M. Z. Rong, M. Q. Zhang, Y. Liu, G. C. Yang, and H. M. Zeng, *Compos. Sci. Technol.,* **61**, 1437 (2001).
9. X. Li, L. G. Tabil, and S. Panigrahi, *J. Polym. Environ.,* **15**, 25 (2007).
10. D. Bachtiar, S. M. Sapuan, and M. M. Hamdan, *Mater. Des.,* **29**, 1285 (2008).
11. D. Bachtiar, S. M. Sapuan, and M. M. Hamdan, *Polym. Plast. Technol.,* **48**, 379 (2009).
12. D. Bachtiar, S. M. Sapuan, and M. M. Hamdan, *Int. J. Auto. Mech. Eng.,* **1**, 79 (2010).
13. J. M. Felix and P. Gatenholm, *J. Appl. Polym. Sci.,* **42**, 609 (1991).
14. W. S. Chow and K. H. Ooi, *Malay. Polym. J.,* **2**, 1 (2007).
15. J. Gassan and A. K. Bledzki, *Compos. Sci. Technol.,* **59**, 1303 (1999).