© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.660.588
Revised: 06.08.2014
Accepted: 12.08.2014

Investigation on the Tensile Strength of Treated and Untreated Woven Sugar Palm Fibre Reinforced Composites

Shahruddin Mahzan[1,a], Wahieda M. Bahtiar[1,b] and Zaleha Mohamad [1,c]

[1] Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

[a]sharudin@uthm.edu.my, [b]wahieda.bahtiar@gmail.com, [c]zaleha@uthm.edu.my

Keywords: Woven Sugar Palm Composite, Tensile Strength, Chemical Treatment.

Abstract. Natural fibres offer environmental benefits such as biodegradable and can be obtained from renewable resources. However, there is lack of investigations done to characterize and compare different types and orientation done on the natural fibres. This paper determines the tensile strength of sugar palm fibres under various treatment processes. The composites were fabricated using woven sugar-palm fibre treated with alkali and acid and used epoxy resin as the matrices for the composite. The tensile test was done to determine the tensile strength of the composite and the surface morphological analysis was done using SEM. The results demonstrated that the composite with the alkali treated fibres produced higher tensile strength compared to untreated and acid treated fibres. With these properties, it shows that treated woven sugar-palm fibre composite can withstand high stress load during operation compared to untreated fibres reinforced composites.

Introduction

Natural fibres offer environmental benefits such as biodegradable and can be obtained from renewable resources. Natural fibres are usually low in density, have low costs since it is a renewable resource, nonabrasive nature to machine, low energy consumption, high specific property, and biodegradable and also have acceptable mechanical properties [1]. Natural fibre also offers environmental advantage such as reduced dependence on non-renewable energy or material sources, lower pollutant emissions and lower the greenhouse gas emission. Although the natural fibre has been proved to be practical to replace the synthetic fibre, there are still some disadvantages that make a pulls back to the synthetic fibres replacement. One of the most significant drawbacks in the natural fibre reinforced composites is that the natural fibre has poor compatibility of the fibre and the matrix due to the hydrophilic characteristic of the cellulose and the hydrophobic nature of matrix material. This leads to poor interfacial adhesion between the fibre and the matrix as well as poor fibre dispersion [2]. Bachtiar et al. [1] stated that the natural fibres can vary a lot in its properties due to the influence of their growing conditions, the fibres processing technique, the fineness of the fibre and the sample test-length, which can make accurate predictions of the respective composite properties difficult. Moreover, the natural fibres have a complex structure of elementary fibres which consists of cellulose, hemicelluloses, pectin, lignin, etc. and thus they are not considered in the same, straightforward way as monofilament fibres [3].

Cao et al. [4] described that the untreated fibres were packed together but it got split after treatments. This process is called fibrillation, where the treatment breaks the untreated fibre bundle down into smaller ones by dissolution of the hemicellulose. This process will increase the effective surface area available for contact with the matrix, and hence the interfacial was improved. Fibres can be treated with several chemical solutions that suit the purpose of to change the surface tension which can help to improve their interfacial properties in the polymer matrix and to reduce the moisture uptake. The improvement on the interfacial properties of the fibre can improve the mechanical and physical properties of the composites [5 – 7]. Generally, there are two methods to modify the surface of the natural fibres which are physical and chemical methods [8-9]. Physical treatments can be applied by using cold plasma treatment, corona treatment, etc. while chemical treatment that are always used are maleic anhydride, organosilanes, isocyanates, sodium hydroxide, hydrochloric acid, permanganate and peroxide.

In term of strength, natural fibres are still inferior by the synthetic fibres. The sugar-palm fibres come out with several types and shapes which are long, short, whiskers, random, woven, etc. Different types and orientations are expected to behave in different characteristics. However, there are less investigation done to characterise and compare the different types and orientation of the natural fibres. Therefore, it is necessary to investigate the tensile properties of the woven type and the possible improvement by chemical treatments. In this study, the tensile properties of sugar-palm fibre under various treatment processes were investigated. SEM has been used to investigate the morphology of the fibre surface and the fracture surface of sugar-palm fibre reinforced epoxy composites.

Materials and Methodology

This investigation used the sugar palm fibres, demonstrated in Fig.1. No chemical treatment or surface cleaning was made in order to simulate the original strength of the fibres. Retting process was applied in order to separate the stalk from the core of the fibre.

Fig.1: Bundle of sugar palm fibres

The 0.5M of Hydrochloric acid (HCL) and 5% of Sodium Hydroxide (NaOH) were used as chemical treatment solutions. After treatment, the sugar-palm fibres were rinsed with distilled water for few times in order to remove remaining solution that sticks to the fibres during the treatment process. The fibres were then dried for 24 hours in room temperature to ensure that it is completely dried. The dried sugar palm fibres were woven in order to orientate the fibre in the composite material. The fibres were manufactured by hand lay-up method. The matrix used for this composite was epoxy resin group with the ratio between resin and hardener were 2:1 by weight. Then, the matrix was poured over the woven fibre and compressed to distribute evenly until it achieved thickness between 4.5 – 5.0 *mm*. The mixture was then pressed and pushed down with a roller to remove bubbles. The composite was left to dry with curing time around 20 – 24 hours applied at room temperature, until the composite plate dried evenly. The samples were cut into several pieces before tested. The tensile test was performed using a universal testing machine, following the *ASTM* D3039 (2000) specifications. The specimens were tested at a crosshead speed of 2 *mm/min* with capacity load of 5*kN*. All samples underwent a coating process, where the samples were coated by gold dust before starting the *SEM* analysis because the matrix used; epoxy resin is not an electric conductor.

Results and Discussion

Tensile Strength. The tensile properties of sugar palm fibre/epoxy composites were summarised in Table 1. The natural (untreated) samples have the lowest tensile stress with 24.07 MPa while the alkali samples have the highest reading among all samples, with 29.97 MPa.

Table 1: Tensile test result of sugar-palm / epoxy composites

Sugar-palm Fibre Treatment	Range of Tensile Stress (*MPa*)	Average Tensile Stress (*MPa*)
Natural (Untreated)	24.07 – 27.13	25.75
Alkali	25.96 – 29.97	27.92
Acid	25.32 – 27.02	26.41

Fig. 2 demonstrated the comparison in tensile stress obtained in the current investigation with previous results obtained from [10]. It shows that the woven type composites demonstrated better performance compared to other type of fibres. The chopped untreated fibre composite has the lowest tensile stress with 14.52 MPa while the woven alkali treated fibre composite has highest tensile stress with 27.92 MPa. The fibres treated with alkali had the highest tensile stress compared to all with the untreated and acid treated fibres with 27.92 MPa. The value of acid treated and natural (untreated) fibres are slightly lower than the tensile stress of alkali treated sugar-palm/epoxy composites about 5% and 8% where its value of tensile stress are 26.41 MPa and 25.75 MPa respectively. All three woven fibres (natural (untreated), alkali treated and acid treated) has a higher tensile stress with 25.75 MPa, 27.92 MPa and 26.41 MPa respectively with average of 83.84% improvement from the tensile stress of the chopped untreated fibre. In summary, the difference in the tensile stress is due to the better interfacial adhesion of tensile treated fibre compared to other fibres.

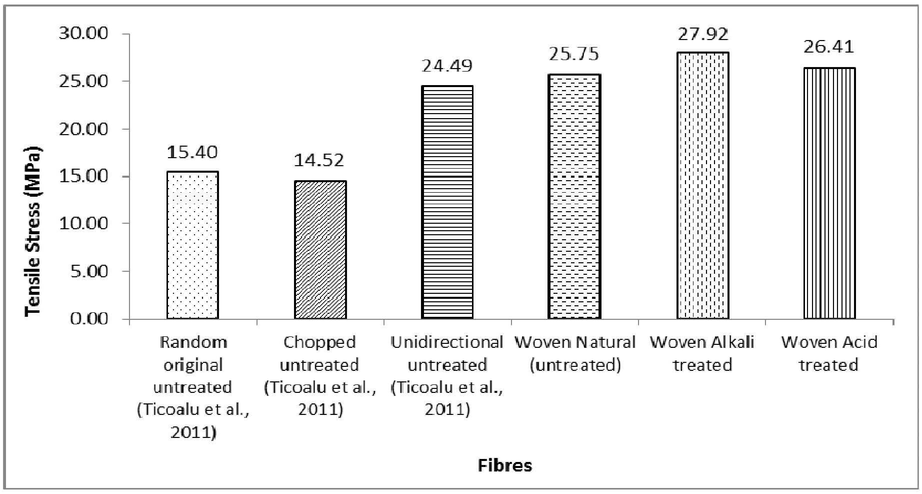
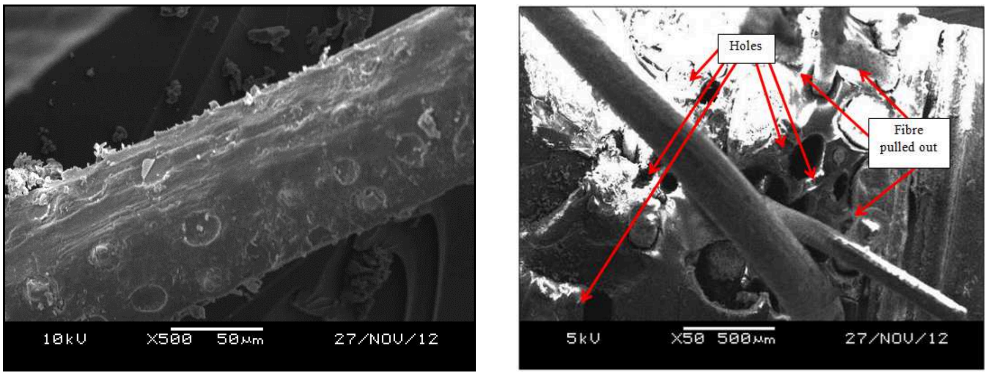


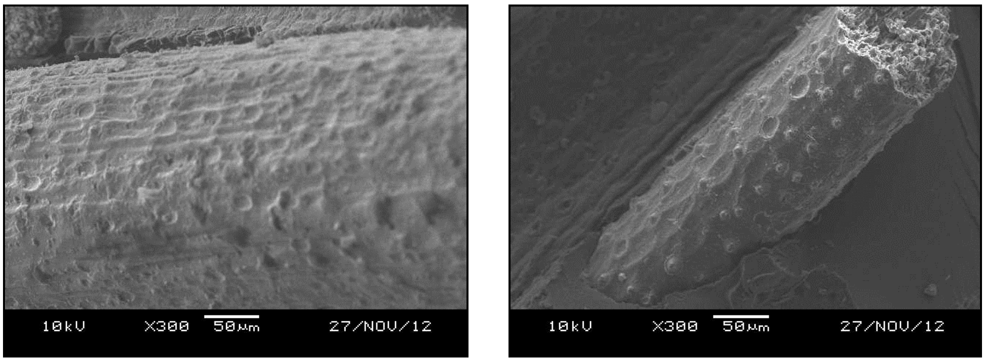
Figure 2: Tensile stress of sugar-palm fibre composites with different orientation

SEM Analysis. The SEM analysis shows that the surfaces of the natural (untreated) sugar-palm fibre were covered with the outer layer of hemicellulose and pectin, demonstrated in Fig. 3. This outer layer gives protection to the fibre from weather and heat degradation. However, this layer does not have strong bonding with the second layer which consists of lignin and crystal cellulose. This is due to the poor compatibility of this layer with the matrix. The weak bonding between the fibre and matrix is indicated by the holes on the fracture surface as a result of the pull-out of the fibre from the matrix locking, as in Fig.3 (b). There were many holes and fibre pulled-outs left on the matrix as a result of poor bonding between the fibres and the matrix, resulted in lower values of tensile strength.



(a) (b)

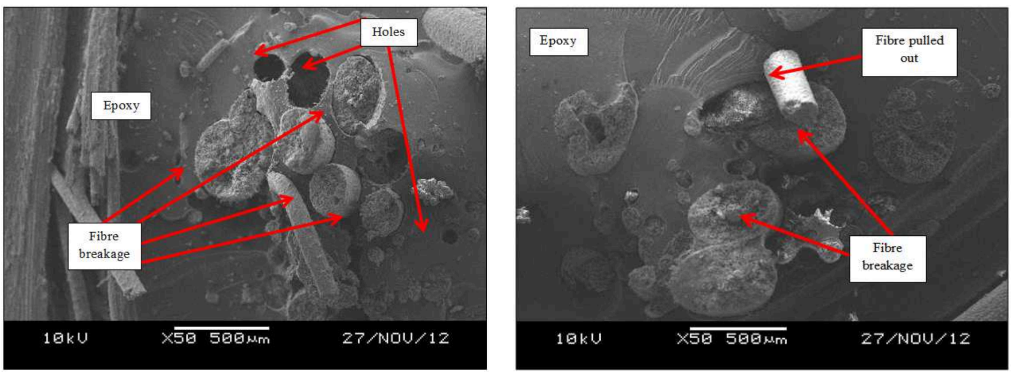
Fig. 3: SEM micrograph of (a) the natural (untreated) fibre and (b) fractured surface of the natural (untreated) fibre composite



(a) (b)

Fig. 4: SEM micrograph of (a) alkali treated fibre, and (b) acid treated fibre

Fig.4 shows that the surfaces of the alkali and acid treated fibre were smoother as compared to the natural fibre. This was due to the removal of the outer layer of hemicelluloses and pectin during the NaOH and HCl treatment. The removal of the outer layer of hemicellulose and pectin had led to improvement of the interfacial characteristic of the composites. It strongly affected the interfacial shear, normal stresses and fracture characteristics of the fibre; and it also improved the tensile strength of the sugar-palm fibre reinforced composites. On the other hand, the second layer, which consists of lignin, held the cellulose cell together and this provide strength to the fibre.



(a) (b)

Fig. 5: SEM micrograph of fractured surface of (a) the alkali treated, and (b) acid treated fibre composites

Further investigation on the microstructure of fractured surfaces shows that the number of holes was reduced, as demonstrated both in Fig.5 (a) and (b). There were less fibre slippages that causes the fibre pulls out and holes thus increased the number of fibre breakage. It justified why the tensile and strength of the treated fibre composites were higher than the untreated fibre composites.

Summary

The tensile strength of treated and untreated woven sugar-palm fibre reinforced epoxy composite was investigated. The results show that chemical treatment on the fibre has improved the tensile strength of fibre reinforced composites. The highest tensile strength was obtained for alkali treated fibre, followed by acidic treated and untreated fibres. By comparing the tensile stress of sugar-palm fibre composite with different orientation, it was observed that the chopped untreated fibre composite has lowest tensile stress with 14.52 MPa while the woven alkali treated fibre composite has highest tensile stress with 27.92 MPa, an improvement of 84 percents. This recommends the viability of woven sugar-palm fibre reinforced composite as a replacement for the synthetic fibre which can withstand high stress load during operation.

Acknowledgements

The author gratefully acknowledges the financial support provided by Universiti Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia under a Grant ERGS, E009.

References

[1] D. Bactiar, S. M.Sapuan and M.M. Hamdan, Flexural properties of alkaline treated sugar palm fibre reinforced epoxy composites, Int. J. of Auto and Mech. Eng., (2010) 79-90.

[2] M.R. Ishak, Z. Leman, S.M. Sapuan, M.Y. Salleh and S. Misri, The effect of sea water treatment on the impact and flexural strength of sugar palm fibre reinforced composites, Int. J. of Mech.and Mtrls Eng., (2009) 316-320.

[3] N.D. Saheb, and J.P. Jog, Natural fiber polymer composites: A review, Adv. in Polymer Tech., (1999) 351–363.

[4] Y. Cao, S. Shibata and I. Fukumoto, Press forming short natural fibre-reinforced biodegredable resin : Effect of fibre volume and length on flexural properties, Polymer Testing, (2005) 1005 - 1011.

[5] Y. Li, Y.W. Mai, and L.Ye, Sisal fibre and its composites: A review of recent developments, Composites Sci. and Tech., (2000) 2037-2055.

[6] X. Li, L.G. Tabil and S. Panigrahi, Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites: A Review, J.of Polymers and the Env., (2007), 25-33.

[7] M.A. Sawpan, K.L. Pickering and A. Fernyhough, Effect of various chemical treatments on the fibre structure and tensile properties of industrial hemp fibres, Composites : Part A, (2011) 888-895.

[8] P.J. Herrera-Franco and A.Valadez-Gonzalez, Mechanical properties of continuous natural fibre-reinforced polymer composites, Composites Part A: App. Sci. and Manufacturing, (2004) 339-345.

[9] D. Bachtiar, S.M.Sapuan and M.M. Hamdan, The effect of alkaline treatment on tensile properties of sugar palm, Mtrls and Design, 29 (2008) 1285–1290.

[10] A. Ticoalu, T. Aravinthan and F. Cardona, Experimental investigation into gomuti fibres/polyester composite, Proc.of 21st Australasian Conf.on Mech.of Struc. and Mtrl. (2011).