

## Challenges for Kenaf Fiber as a Reinforcement Material: A Review

M.A. Hassan<sup>1,a</sup> and A.E. Ismail<sup>2,b</sup>

<sup>1,2</sup> Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia  
Parit Raja, Batu Pahat, 86400 Johor, Malaysia

<sup>a</sup>mohdaimanhassan7@gmail.com, <sup>b</sup>emran@uthm.edu.my

**Keywords:** Kenaf Fiber, Interphase, Water Absorption, Chemical Treatment, Volume of Fiber Fraction, Reinforcement, Fabrication Process.

**Abstract.** In order to reduce cost of production and decrease environmental pollution, so many research work has been conducted and still ongoing as to the possibility to use kenaf fiber in high technologies production. It shows that kenaf fiber have potential reinforced fiber in thermosets and thermoplastics composites. This paper presents the various of challenges to produce kenaf as a reinforcement which mean to identify the limit of kenaf fiber performance after over all of challenging factor. The main factor that touch on interphase, water absorption, chemical treatment and fiber fraction which mean affect the performance of kenaf fiber as a reinforcement are discussed.

### Introduction

Kenaf is one of the natural fibers used as reinforcement in Polymer Matrix Composites (PMC). Kenaf *Hibiscus cannabinus*, L. has been found to be an important source of fiber for composites, and other industrial applications [1]. Kenaf is well known as a cellulosic source with both economic and ecological advantages because in 3 month after sowing the seeds, it is able to grow under a wide range of weather conditions, to a height of more than 3 m and a base diameter of 3-5 cm [2]. This statement is supported by previous studies, which mentions that growing speed may reach 10 cm/day under optimum ambient conditions [3]. Kenaf was priced at RM 1700 to RM2200 per tons in 2014, and the price was depend on the type of kenaf fiber [4]. From the viewpoint of energy consumption, it takes 15 MJ of energy to produce 1 kg of kenaf, whereas it takes 54 MJ to produce 1 kg of glass fiber [3]. Raw kenaf fiber obtained from outer bark, is actually a bundle of lignocellulosic fibers. The fiber bundle size depends on the number of ultimate cells in each bundle. Most lignin is present between the ultimate cells. Kenaf contains approximately 0.7% of cellulose, 21.6% of lignin and pectin and other components. Lignin must be extracted to separate the fibers [5]. Han stated the kenaf fibers are shorter at the bottom of the stalk and longer at the top. The increase in length from the bottom to the top was not gradual, but S-shaped [6]. There is more variation of the fiber length at the top of the stalk. Also, the longest fibers are located at the top. On the other hand, different parts of a plant have different chemical and physical properties. That is, the chemical compositions and fiber properties of plant tissue taken from the roots, stem, trunk and leaves are different and are also different at different stages of the growing season [7]. Fiber length increases in the early part of the growing cycle, and then decreases again for the plant matured [8]. This may be an advantage in harvesting of the fiber before the plant matures. The research of natural fiber reinforced composites is growing rapidly due to their mechanical properties, low cost, processing advantages and low density. The availability of natural fibers such as kenaf in Asia is more and also has some advantages over traditional reinforcement materials in terms of cost, density, renewability, recyclability, abrasiveness and biodegradability. The performance of the fiber reinforced composites mainly depends on the fiber matrix and the ability to transfer the load from the matrix to the fiber [9].

## Challenges for kenaf fiber as reinforcement

**Interface:** The main disadvantage encountered during the addition of natural fibers, including kenaf fiber into a polymer matrix, is the lack of good interfacial adhesion between the two components, which results in poor properties in the final product. Polar hydroxyl groups, on the surface of the kenaf fiber, have difficulty forming a well bonded interphase with a relative nonpolar matrix, as the hydrogen bonds of the fiber surface tend to prevent the wetting of the filler surface. Furthermore, the incorporation of kenaf fiber as filler in a polymer matrix is often associated with agglomeration, as a result of insufficient dispersion caused by the tendency of fibers to form hydrogen bonds with each other. Fiber–matrix interfacial adhesion can be improved with chemical modifications on the fiber and one of the familiar and effective modifications applied on kenaf fiber, is an alkaline treatment based on sodium hydroxide (NaOH) [1].

**Water absorption:** It is important to study the water absorption behavior in order to estimate, not only the consequences that the absorbed water may cause, but also the durability of the natural fiber composites under water. Generally, most researchers agree that moisture penetration into composite materials is conducted by three different mechanisms. The main mechanism consists of the diffusion of water molecules into the micro-gaps between polymer chains. The second mechanism involves capillary transport into the gaps and flaws, which interfaces between the fiber and the matrix due to incomplete wettability and impregnation. The third mechanism involves the transport of micro-cracks in the matrix, formed either during the compounding process, or due to fiber swelling. Matrix such as polyester, are easily hydrolyzed by moisture, resulting in a molecular weight reduction. The rate of this hydrolytic degradation is dependent on temperature and humidity [1]. This would lead to an extensive loss in mechanical properties of natural fiber based composites, especially kenaf fiber reinforced composites in a humid environment.

**Chemical treatment:** Chemical modification or treatment of the natural fibers especially kenaf, is generally carried out using reagents, which contain functional groups that are capable of bonding with the hydroxyl group from the natural fibers. Several types of chemical modifications have been reported in previous literatures, which include alkaline treatment, silane treatment, isocyanate treatment, and acetylation [10]. Alkaline treatment or mercerization is one of the most widely used chemical treatments for natural fibers, especially the kenaf fiber when reinforcing thermoplastics and thermosets [11]. This modification is carried out by immersing the fibers in a NaOH solution for a period of time [12]. The important modification that is done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes certain hemicelluloses, lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes cellulose, and exposes the short length crystallites. Alkaline treatment leads to fibrillation of the fiber bundles into small fibers. In other words, this treatment reduces fiber diameter and thereby increases aspect ratio. The addition of aqueous sodium hydroxide (NaOH) to the natural fiber promotes the ionization of the hydroxyl group to the alkoxide [13]. It is reported that alkaline treatment has two effects on the fiber, first it increases surface roughness, resulting in better mechanical interlocking and second it increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites. Consequently, alkaline treatment has a lasting effect on the mechanical behavior of natural fibers, especially on their strength and stiffness performance [13]. Silane treatment is used for coupling agents allow natural fiber to adhere to a polymer matrix, thus stabilizing the composite material. Silane coupling agents may reduce the number of cellulose hydroxyl groups in the fiber matrix interface. In the presence of moisture, the hydrolysable alkoxy group leads to the formation of silanols [1]. The silanol then reacts with the hydroxyl group of the fiber, forming stable covalent bonds to the cell wall that are chemisorbed onto the fiber surface. It was assumed that the hydrocarbon chains produced by the silane application influenced the wettability of the fibers, thus improving the chemical affinity of the polymer matrix. Silane treatment also enhanced

the tensile strength of the composites, minimized the effect of moisture on the composite's properties, increased adhesion, and thereby, the composites strength [12]. Silane treatment has been introduced to kenaf fiber by previous researchers over the past few years [11]. Magnificent results were recorded for treated composites, in terms of interfacial adhesion between kenaf filler and the polymer matrix.

**Fiber fraction:** A more previous study of the fiber content on mechanical properties of kenaf fiber reinforced composite was carried out by Nishino [14]. Generally, optimum tensile properties and Young's modulus are dictated by the volume of reinforcing fiber used for the composites. From the previous study, it shows the research on kenaf natural fibre is increasing among researchers [17].

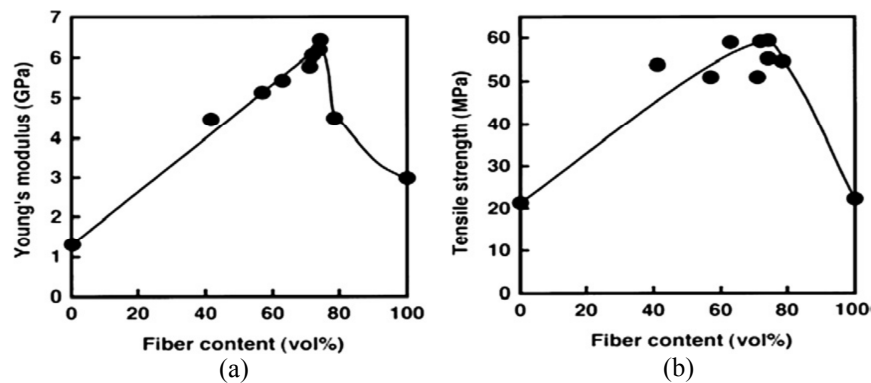


Figure 1: Relationship between (a) Young modulus, (b) the tensile strength, and the kenaf fiber content of kenaf fiber [1]

As can be seen in Figure 1, both properties increased with the increase of fiber content and showed the maximum values (Young's modulus 6.4 GPa, and the tensile strength 60 MPa) around a fiber content of 70 %. The decrease in the mechanical properties of the composite with the fiber content above 70 % could be due to insufficient filling of the matrix resin.

**Reinforcement:** Generally the main type of reinforcement are divided into fibers, filled, whiskers, flake and particulates. Requirement as a reinforcement is stronger than matrix, stiffer than matrix and capable to change failure mechanism to advantage of composite. A challenge of reinforcement is to provide a constant structure by using natural fiber. Recently, some of studies have been carried out to determine the effects of various variables on energy absorption capability of composites material under compressive loading [16]. According to some literature [18, 19], woven fibre is have good mechanical properties compare to non-woven. According to the result, it can be concluded that woven structure exhibited excellent mechanical behaviour under tensile, flexural, and impact loading compare to non-woven composite. It also mention that, tensile, flexural and impact strength of WJF (Woven Jute Fabric)/PLLA composite is higher at warp direction compared to weft direction.

**Fabrication process:** There are many type of method to fabricate a composite and divided by two groups which are wet layup and dry layup. For example spray layup, compression molding for wet layup and it messy than dry layup which is vacuum infusion. Vacuum infusion is selected for the fabricate a sample because this method used offers more benefits than hand lay-up method due to the better of fibers to resin ratio resulting in stronger and lighter laminates. Figure 2 shows the vacuum infusion setup and process. The kenaf/polyester fabricated composites by vacuum infusion process has the superior tensile strength compared to hand lay-up method, where tensile strength and Young's modulus is higher than hand lay-up method [15].

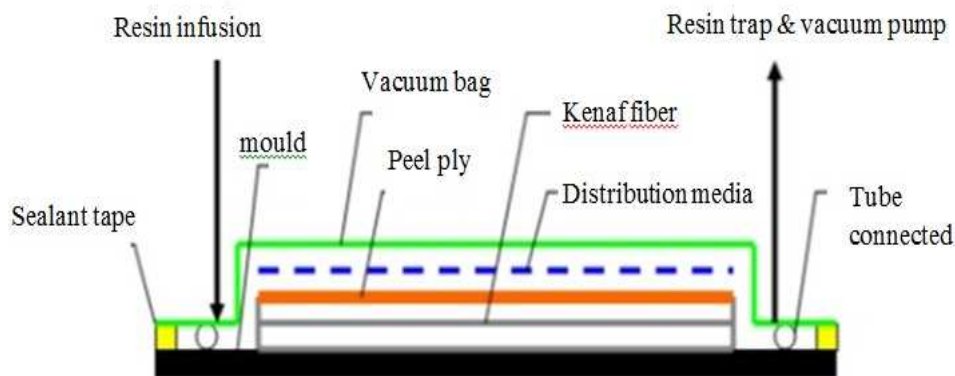


Figure 2: The vacuum infusion configuration [15]

Figure 3 shows the fragmentation of hand lay-up and vacuum infusion fabrication and it was observed that hand lay-up sample have no fibers pull out compared to vacuum infusion method. However, there is a lot of void on the hand lay-up sample. For vacuum infusion process, samples appear woody due to adhesion form between fibers and matrix [15].



(a)



(b)

Figure 3: a) Fracture specimens of kenaf/polyester composite fabricated by hand lay-up method.  
b) Fracture specimens of kenaf/polyester composite fabricated by vacuum infusion process [15]

## Conclusion

Based on previous research, it shows the challenges to produce kenaf fiber as a reinforcement is one of the main factor that affect to composite performance. Overall, the use of kenaf fiber as a reinforcement in composite can help to generate jobs in both rural and urban areas, in addition to helping to reduce waste, and thus, contributing to a healthier environment. However, looking at future demands, more crucial studies are required on product commercialization and manufacturing processes in order to compete with synthetic fiber performance.

## Acknowledgements

Authors acknowledge Universiti Tun Hussein Onn Malaysia (UTHM), Office for Research, Innovation, Commercialization and Consultancy (ORICC) and Ministry of Education Malaysia for sponsoring this work through Fundamental Research Grant Scheme (FRGS) vot. 1424.

## References

- [1] Akil, H. M. Kenaf fiber reinforced composites: A review. *Material and Design* 32.8 (2011): 4107-4121.
- [2] Aziz SH, Ansell MP, Clarke SJ, Panteny SR. Modified polyester resins for natural fiber composites. *Compos Sci Technol* 2005;65:525–35.
- [3] Nishino T. *Green composites: polymer composites and the environment*. United Kingdom, 2004.
- [4] LKTN. Harga kenaf 2014. Lembaga Kenaf dan Tembakau Negara LKTN. 2 May 2014, from <http://www.lktn.gov.my/news.php?item.47>.
- [5] Abdalla, A. Ab. Rashdi. and Khalina, Bt. Abdan. Review of kenaf fiber reinforced polymer composites. *POLIMERY*. 2009: p. 775-888.
- [6] Han, J.S. Mianowski, T. Lin, Y. Validity of Plant Fiber Length Measurement: A Review of Fiber Length Measurement Based on Kenaf as a Model In *Kenaf Properties, Processing and Products*, Mississippi State University. Mississippi State (1999), Chap 14, pp.149-167.
- [7] Rowell, R. M. Han, J. S. Changes in Kenaf Properties and Chemistry as a Function of rowing Time In: *Kenaf Properties, Processing and Products*, Mississippi State University. Mississippi State (1999), Chap 3, pp. 33-41.
- [8] Cho, J. Park, Y. Lee, B. Han, J.S. Miyashita, E. S. Properties of Kenaf from Vanous Cultivars, Growth, and Pulping Conditions, Fifth Chemical Congress of North America, November 2001, Cancun, Mexico.
- [9] Shibata, S. Bozlur, R. M. Fukumoto, I. and Kanda, Y. Effects of Injection Temperature on Mechanical Properties of Bagases/PP InjectionMolding Components, *BioResources*, (2010) Vol. 5, pp. 2097-2111.
- [10] George, J. Sreekala, M. Thomas, S. A review on interface modification and characterization of natural fiber reinforced plastic composites. *Polymer Engineering Science*. 2001.41:1471-85.
- [11] Huda, M.S. Drzal, L.T. Mohanty, A.K. Misra, M. Effect of fiber surface-treatments on the properties of laminated biocomposites from polylactic acid (PLA) and kenaf fibers. *Composite Science Technology*. 2008. 68:424–32.
- [12] Li, X. Tabil, LG. Panigrahi, S. Chemical treatments of natural fiber for use in natural fiber-reinforced composites: a review. *Environment Polymer*. 2007. 15:25–33.
- [13] Bogoeva, Gaceva, G. Avella, M. Malinconico, M. Buzarovska, A. Grozdanov, A. Gentile, G. Natural fiber eco composites. *Polymer Composite* 2007. 28: 98–107.
- [14] Nishino, T. Hirao, K. Kotera, M. Nakamae, K. and Inagaki, H. Kenaf reinforced biodegradable composite. *Composite Science Technology* 2003. 63:1281.
- [15] Mohd Yuhazri, Y. and Phongsakorn, P.T. A Comparison Process between Vacuum Infusion and Hand-lay-up method towards Kenaf/Polyester composites. *International Journal of Basic & Applied Sciences*, 2010. 10: 54-57.
- [16] A.E Ismail, Effect of foam density and wall thickness interactions on the energy absorption performances. *Applied Mechanics and Materials* (2013) 315:665-669.
- [17] M.N Roslan, A.E Ismail, M.Y Hashim, M.H Zainulabidin, S.N.A Khalid, Modelling analysis on mechanical damage of kenaf reinforced composite plates under oblique impact loadings, *Applied Mechanics and Materials* 465 (2014) 1324-1328.
- [18] A.E Ismail, M.H Zainulabidin, M.N Roslan, A.L.M Tobi, N.H.M Nor. Effect of velocity on the impact resistance of woven jute fiber reinforced composites. *Applied Mechanics and Materials* (2014) 465:1277-1281.
- [19] A.E Ismail, M.K Awang, M.H Sa'at, Tensile strength of natural fiber reinforced polyester composite, *AIP Conf. Proc.* 909 (2007) 174-179.