The Effect of Fiber Length on Mechanical Properties of Epoxy Composites Reinforced by the Fibers of Vetiver

P. Kongkaew[1*], D. Kiannok[2], P. Saetang[2] and L. Teekhayupak[2]

[1]Program of Physics, Faculty of Science, [2]Program of Physics, Faculty of Education,

Rajabhat Maha Sarakham University, 80 Nakhonsawan Road,Muang Maha Sarakham, 44000

*E-mail: Ch_ko29@hotmail.com

Abstract

The effects of fiber length on mechanical properties of epoxy composites reinforced by the fibers of vetiver were analyzed. Five different specimens were made by varying the length of the fiber 3, 5, 7, 9 and 13 mm at 12% wt. fiber loading using the hand lay-up method. The tensile strength, tensile modulus, flexural strength, flexural modulus and impact strength of the composite were investigated and microstructure of the composite material with Scanning Electron Microscopy (SEM). Experimental results show that the tensile strength, tensile modulus and impact strength increased with increase fiber length, which the tensile strength, tensile modulus and impact strength had their maximum values of 25.65 MPa, 823.17 MPa and 19.49 kJ/m^2 respectively at 13 mm fiber length suggesting critical fiber length for effective and maximum stress transfer. However, the flexural strength, maximum values at 30.05 MPa at 7 mm fiber length. This is consistent with the inspection results the microstructure of the composite material.

Keywords: Mechanical properties: Vetiver fiber: Composite materials

Introduction

Composites reinforced with natural fibers have become the new materials that are used as high strength and stiffness, nature material and environmental ‘friendliness’ [1-2]. In addition, they also use recycled, renewable and material costs are very low. [3]. The problem in the current environment and ecosystems can be resolved by developing biodegradable composites using natural fibers. Today there are varied types of natural fibers and diversity continues to increase. Some examples that can be used, such as hemp, jute, kenaf, sisal, bamboo and oil palm fiber. However, in this study, a vetiver fiber is used as a material to reinforce a polymer matrix in epoxy composite. Vetiver grass is a one plant of interest when compared with other plants. Vetiver grass is a plant native to the tropics, which has adapted well to the different environment conditions [4]. According to the primary purpose of developing the agriculture of Thailand, where the vetiver grass is a plant for conserving of soil and water, especially the steep hillside.

In Thailand, the government is encouraging farmers to grow this plant, but there are some farmers that are beneficial to agricultural areas to conserve soil and water, which probably will not see results in terms of revenue is apparent. For this reason it became the inspiration of this research will make use of vetiver grass as a reinforcement in polymer composites that can help farmers earn extra income in some increase. Therefore, in this work the vetiver grass is chosen to be the sources of fibers for producing reinforced composites and investigate the effects of fiber length on mechanical properties of epoxy resin composites.

Materials and Methods

Materials

The natural fiber is a vetiver fiber collected from Ban Bokeaw, Kalasin province, Thailand as shown in Figure 1. In this research, vetiver root fiber with 12% wt. from vetiver plant were used. The age of vetiver plant is around 1-2 years. The properties of vetiver fibers are shown in Table 1. Epoxy resin and hardener are purchased from Polyline Ltd., Phatumtani, Thailand.

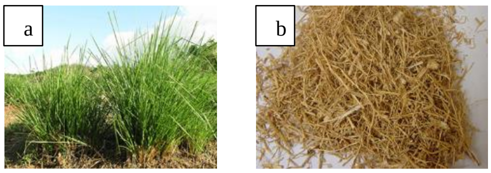

Figure 1 Raw material (a) Vetiver plant and (b) Vetiver root fiber

Preparation of Composite and Testing

In this research, the studies were carried out to analyze and investigate the fiber length of vetiver fiber reinforced composite material, which effects the mechanical properties as shown in Figure 2.

Firstly, vetiver fibers were extracted from the roots with a pen knife. Secondly, the Vetiver fiber soaked in water and sundried to remove the moisture. After that, the fibers were immersed in NaOH solution (NaOH 97% Acilabscan Ar 1171-P1 KG, 5% by volume) for 3 h [7]. Thereafter, the fibers are washed with water until neutral (pH7). The fibers are then dried to leave it at room temperature for 5 days. Later, the composite is 12% by weight of the fibers were prepared using the fibers of length in the range 3, 5, 7, 9 and 13 mm. A matrix was created by the combination of epoxy resin and hardener in the ratio 10: 1 by weight [5]. The mixture is then poured into the rubber mold. It was executed according to the ASTM test (ASTM D 638 type1 for tensile test, ASTM D790 for Flexural test and ASTM D 256 for Impact test). After that, Mylar films were put at the top and bottom of the specimen in order to obtain a smooth surface. Then, the composite samples were left at room temperature for 7 days to allow the material to be settled and then removed from the mold. Finally, take a sample to test the mechanical properties and the microstructure of the tested composite samples was analyzed by scanning electron microscope (SEM). These studies investigate the effect of fiber length on mechanical properties of vetiver fiber.

Table 1 The properties of vetiver fiber and other natural fiber

Properties	Vetiver[4]	Banana[5]	Hemp[5]	Flax[4]	Plam[6]
Density (g/cm^3)	1.5	1.35	0.3-1.3	1.5	0.7-1.55
Diameter (μm)	100-220	-	-	-	150-550
Tensile Strength (MPa)	247-723	54	90	345-1100	248
Flexural Modulus (GPa)	-	2-5	3-5	-	-
Young' Modulus (GPa)	12.0-49.8	3.48	4.4	27.6	3.2
Elongation at break (%)	1.6-2.4	-	-	2.7-3.2	25
Moist Absorption (%)	-	10-11	10-12	-	-

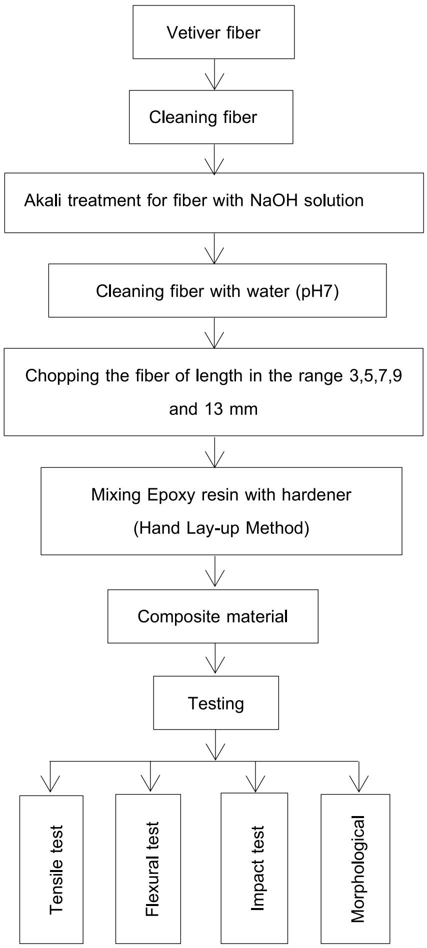

Figure 2 Diagram for this research

Results and Discussion

The characteristics of composites with fiber length showed a significant effect on the mechanical properties of composite materials. The properties of composites under different vetiver fiber length as shown in Table 2.

Tensile Properties

The tensile strength and tensile modulus of epoxy resin composite reinforced with the varies in length of the fiber (in the range 3, 5, 7, 9 and 13 mm) as shown are Figure 3 and Figure 4 respectively.

The results for tensile properties showed that the increase continues with the fiber length are increased to a maximum of about 13 mm (25.65 MPa). The reason for this increase can be explained by the strength properties of composites, these chemical reactions at the interface between the fiber and matrix strong in transferring tensile [8]. From Figure 4 shows clearly that the fiber length increased, resulting the tensile modulus increased. Generally, the thermoset composites show that the trend of the mechanical properties of their increases depending on the length of fiber [9]. According to studies of Doan *et al.* [10] found that the fiber length plays an important role in increasing the mechanical performance of composites reinforced with fibers. The study of Baiardo *et al.* [11] found that the mechanical properties of composite materials reinforced with short fibers that are depended on (i) the natural properties of the fiber and the matrix,(ii) aspect ratio of the fiber and the matrix, volume, distribution lengthwise and orientation of the fibers in the composite, and (iii) effective adhesion between the fibers and the matrix which acts to transfer loads in the composite. However, the tensile strength decreased from 9 to 3 mm fiber length, of which are two main reasons to explain: namely, the existence of defects such as gaps and weakness of the bond between the matrix and the reinforcement of composite materials [12].

Table 2 Mechanical properties of composites

Fiber length (mm)	Tensile strength (MPa)	Tensile modulus (MPa)	Flexural strength (MPa)	Flexural modulus (MPa)	Impact strength kJ/m^2
0	10.24±0.05	89.52±4.08	15.70±1.79	53.64±5.81	13.25±1.83
3	12.1±0.77	309.33±13.20	16.01±1.27	112.11±2.32	13.47±0.28
5	12.97±0.83	325.17±22.30	24.25±0.54	170.32±27.70	13.74±2.38
7	16.22±0.38	379.83±53.60	30.05±0.92	250.64±36.46	14.40±1.14
9	16.83±0.37	382.33±50.80	25.93±1.59	145.01±35.04	18.37±2.64
13	25.65±1.62	823.17±49.70	20.25±2.57	119.82±40.69	19.49±1.50

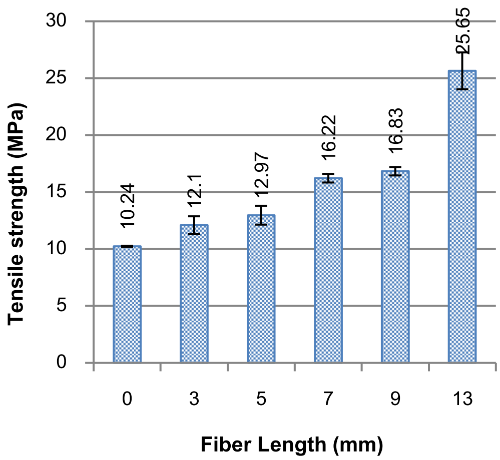

Figure 3 Effect of increasing vetiver fiber length on tensile strength of composite.

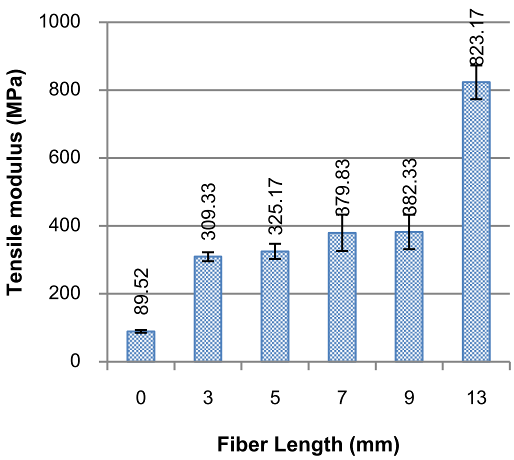

Figure 4 Effect of increasing vetiver fiber length on tensile modulus of composite.

Flexural Properties

The flexural strength and flexural modulus of epoxy resin composite reinforce with the varies in length of the fiber as shown are Figures 5 and 6. It was found that improvement in flexural properties of composites. This is the result obtained whereby the flexural properties increased with increased fiber length from 3 mm to 7 mm, respectively. The flexural properties of 7 mm (30.5 MPa for flexural strength and 250.64 MPa for flexural modulus) length of fiber were found maximum compare to epoxy resin and other lengths by reinforcement of vetiver fiber. It is interesting to note that the flexural properties of the composite, incorporation of fiber length in the polymer composites influence the properties of the composite [13]. Subsequently, the flexural properties decreased as the fiber length increases to 13 mm, which can be caused by improper positioning of the fiber because of the tangle of fiber length increases, as well as the possibility of increasing the area of voids between the fiber and the matrix within the composite. According to Khalil *et al.* [14] showed that the weak bonding between the fibers and the matrix, causing poor flexural properties. The efficiency of stress transfer between the epoxy resin and fiber decreased due to weak interfacial area. Factors effecting the quality of the interfacial bonding depend on the nature of the fiber and the matrix as well as their composition, the aspect ratio of fiber, the type of mixing method in the preparation, manufacturing process conditions and in the treatment of polymer or fiber with the type of chemical used and coupling agent.

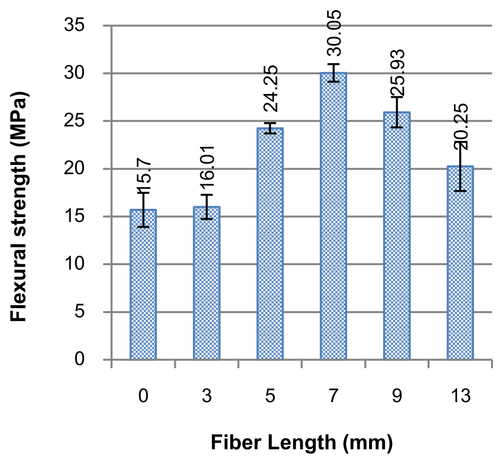

Figure 5 Effect of increasing vetiver fiber length on flexural strength of composites.

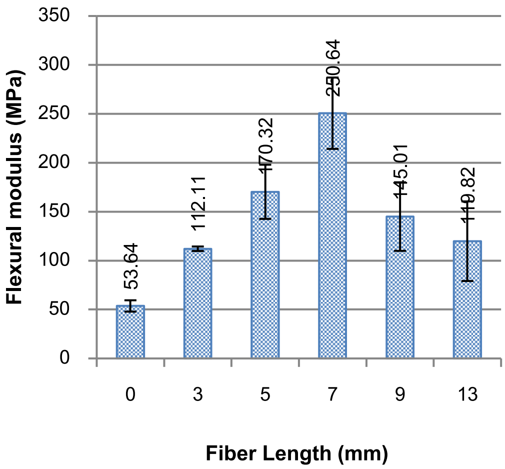

Figure 6 Effect of increasing vetiver fiber length on flexural modulus of composites.

Impact Properties

Figure 7 shows the effect of fiber length on impact strength of the composites which it's shown that improve with increase in fiber length. The impact properties of 13 mm (19.49 kJ/m^2) length of fiber were found maximum compare to epoxy resin and other all the composite. The impact performance of composites depends on many factors such as the failure of the matrix, bonding between the fibers and the matrix and pull out fibers [15].

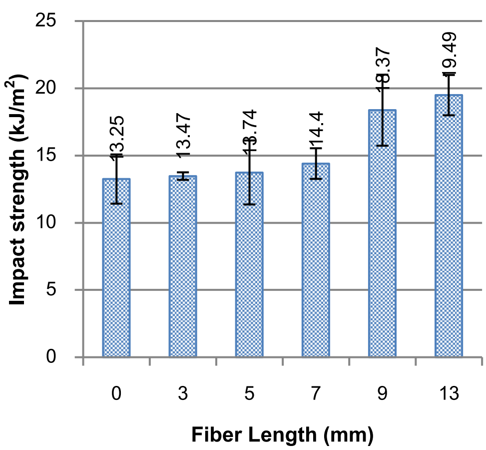

Figure 7 Effect of increasing vetiver fiber length on Impact strength of composites.

Fractured Surface Morphology

The surface morphology for the tested specimen can be completed by using LEO/1450 scanning electron microscope available at Khon Kean University, Khon Kean, Thailand. The SEM images of vetiver fiber reinforced composite after fracture loading defects and fiber pull out are shown in Figures 8, 9 and 10.

The effects of fiber length on mechanical properties of epoxy resin composites reinforced by the fibers of vetiver after tensile test is clearly seen in Figure 8. The Figure 8 (a) shows that there was a small gab around the fibers, which would effect the ability of adhesion between matrix and fibers is poor. Incomplete wettability or bonding between the matrix and fibers during the fabrication of composites probably cause a small gap [12]. As a result, the composites of the composites decreased accordingly [16] Figure 8(b) shows the best properties for 13 mm in length. The crosslinking of the fiber will be able to create load behavior between fiber and matrix sharing, which can be seen clearly in this has been shown in Figure 9. Figure 9(a) shows the images is clear that there is virtually poor interfacial bonding between the fiber and matrix [17]. The presence of uneven fibers in a brittle resin in the vetiver/epoxy is probably the cause of the poor flexural strength [17]. Figure 9(b) shows that 7 mm fiber length of composite have a good adhesion between matrix and fiber. Thus, reinforcement is strongly adhesion to the matrix if they have high strength and stiffness is to be imparted to the composites clearly [18].

SEM photograph of vetiver fiber composite after impact fracture are shown in Figure 10. Figure 10(a) shows the void on the surface caused by pulling out of the fiber will show the poor interfacial bonding between fiber and matrix. Additionally, Figure 10(b) shows that the fiber has offered good strength and energy absorption caused by the fracture itself. Finally, it is evident that the fibers were pulled out with a clean surface.

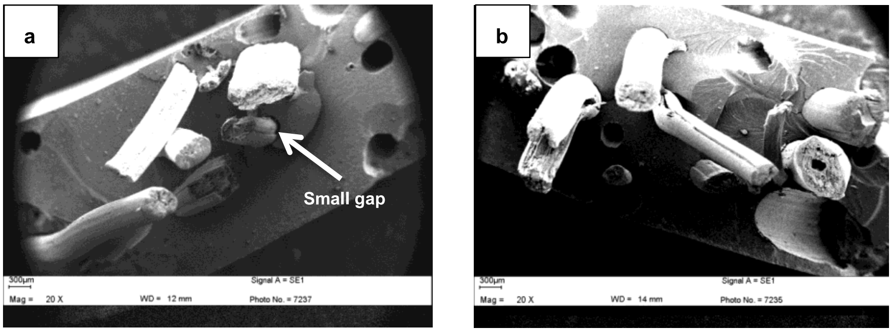

Figure 8 SEM micrographs of composite specimens after tensile testing. (a) 3 mm in fiber length (b) 13 mm in fiber length.

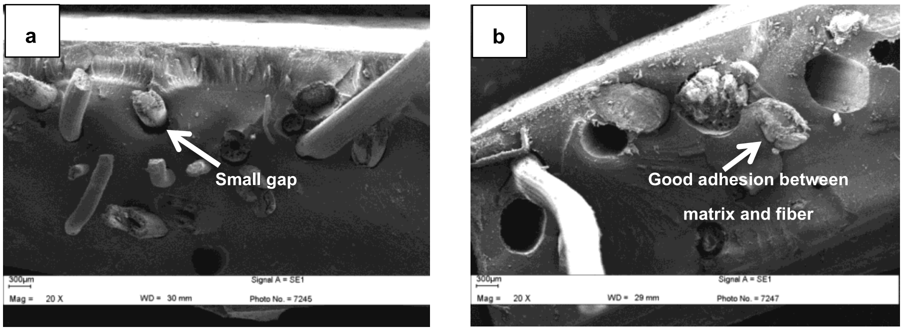

Figure 9 SEM micrographs of composite specimens after flexural testing. (a) 3 mm in fiber length (b) 7 mm in fiber length.

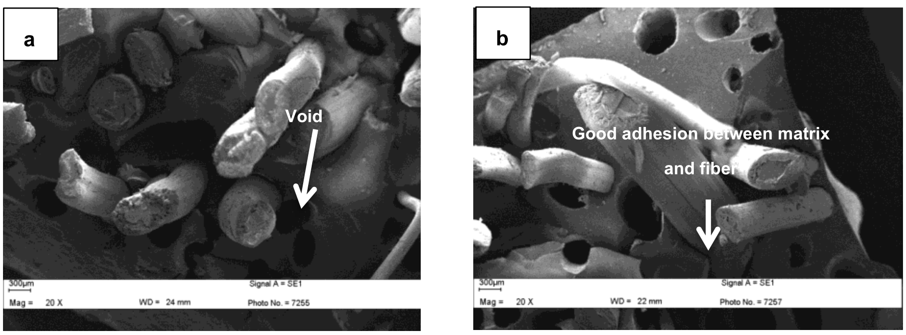

Figure 10 SEM micrographs of composite specimens after impact testing. (a) 3 mm in fiber length (b) 13 mm in fiber length.

Conclusions

The effects of fiber length on mechanical properties of epoxy resin composites reinforced by the fibers of vetiver were investigated. Five levels of fiber length (3, 5, 7, 9 and 13 mm) for vetiver fibers were considered. Based on the result, the following conclusions are drawn

This study has confirmed that vetiver fiber reinforced epoxy resin composites have good mechanical properties such as tensile strength (25.65 MPa), tensile modulus (823.17 MPa), flexural strength (30.05 MPa) and impact strength (19.49 kJ/m^2) of the composites are also greatly effected by the fiber lengths.

Study on the morphology of composites shows the fiber pullout, interfacial characteristic, fiber failure and internal structures of the surfaces are clearly observed.

It is suggested that these vetiver fiber reinforced epoxy resin composites can be used as an alternate material for materials reinforced with synthetic fiber.

Acknowledgments

The author would like to thanks the Institute for Research and Development for funding. Program of Physics, Faculty of Science and Technology, Rajabhat Maha Sarakham University. Department of Mechanical engineering, Khon Kaen University for facilities and greatfully knowledge.

References

[1] Sapuan S.M., et al. (2006). Mechanical properties of woven banana fibre reinforced epoxy composite. *Mater. Des., 27*, 93-689.

[2] Mukhopadhy S. and Srikanta S. (2008). Effect of ageing of sisal fibres on properties of sisal-polypropylene composites. *Polym. Degrad. Stabil. , 93,* 51-2048.

[3] Justiz-Smith N.G., Virgo G.J. and Buchana V.E. (2008). Potential of Jamaican banana, coconut coir and bagasse fibres as composite materials. *Mater. Charact., 59,* 8-1273.

[4] Yupaporn R. et al. (2007). Vetiver- polypropylene composites: Physiccal and mechanical properties. *Composites: Part A., 38*, 590-601.

[5] Bhoopathi R., RaMesh M. and Deepa C. (2014). Fabrication and Property Evualation of Banana-Hemp-Glass Fiber Reinforced Composites. *Procrdia Engineering, 97,* 2032-2041.

[6] Duangkamon K., Phetcharat S. and Laddawan T. (2016). Effect of Fiber Length on Mechanical Properties of Vetiver Fiber Reinforced Epoxy Resin Composite. Rajabhat Maha Sarakham, Maha Sarakham.

[7] Manalo C.A., et al. (2015). Effects of alkli treatment and elevated temperature on the mechanical properties of bamboo fibre-polyester composites. *Composites Part B., 80,* 73-83.

[8] Sandhyarani B., Sanjay K. and Amar P. (2011). Effect of Fiber Length on Mechanical Behavior of Coir Fiber Reinforced Epoxy Composties. *Fibers and Polymers, 12(1),* 73-78.

[9] Luo S. and Netravali A.N. (1999). *Jnl. Mater. sci., 34*, 3709.

[10] Doan T.T.L., Gao S.L. and Mader E. (2006). *Compos. Sci. Technol., 66,* 952.

[11] Baiardo M., Zini E. and Scandola M. (2004). *Appl. Sci. Manufact., 35*, 703.

[12] Raghavendra S., et al. (2012). The Effect of Fiber Length on Tensile Properties of Epoxy Resin Composites Reinforced by the Fibers of Banana. *International Journal of Engineering Research & Technology (IJERT), 1(6)*, 2278-0181.

[13] Dayananda N., et al. (2013). *Journal of Reinforced Plastics and Composites, 27,* 313.

[14] Khalil H.P.S.A., et al. (2012). *Ind. Crop. Prod. 26,* 315.

[15] Sarkar B.K., Ray D. and Bose N.R. (2002). *Compos. A, 33*, 233.

[16] Bachtair D., Sapaun, S.M. and Hamdan M.M.

(2008). The effect of alkaline treatment on the tensile properties of sugar palm fibre reinforced epoxy composite. *Materials and Design*, 1285–90.

[17] Harisha S., et al. (2009). Mechanical property evaluation of natural fiber coir composite. *Materials Characterization, 69*, 4-94.

[18] Mathews F.L. and Rawlings R.D. (1999). Composites Materials Engineering and Science. Chapman and Hall, London.