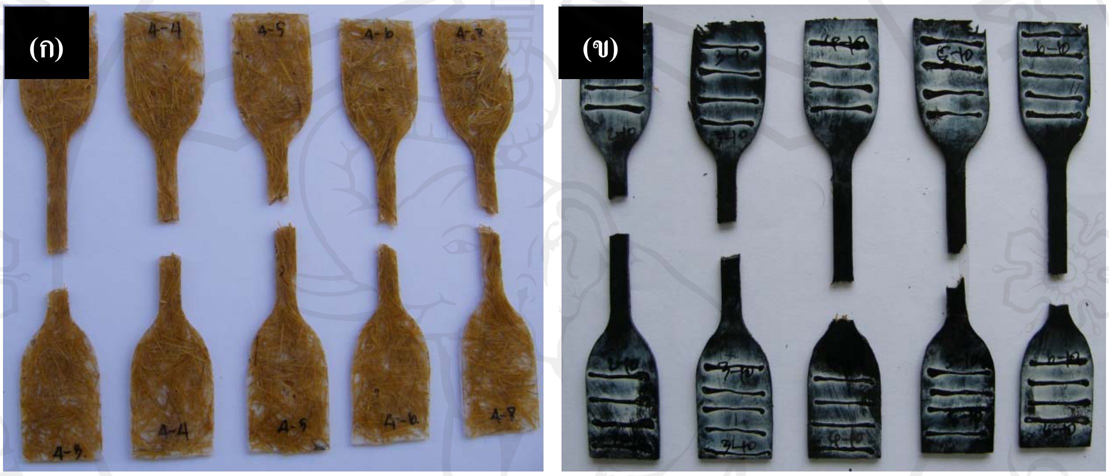
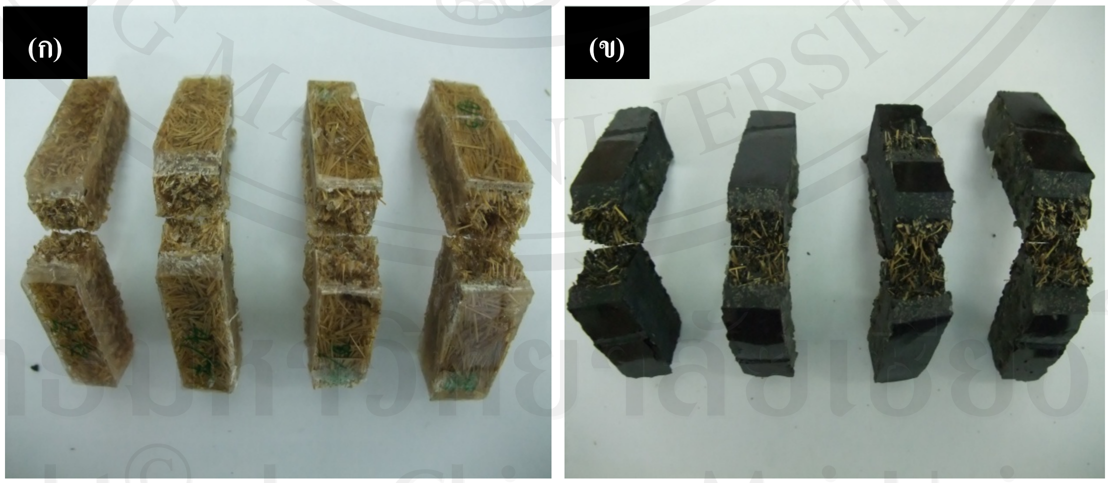
ภาคผนวก

ภาคผนวก ก

ตัวอย่างลักษณะชิ้นงานที่เสียสภาพจากการทดสอบสมบัติเชิงกล



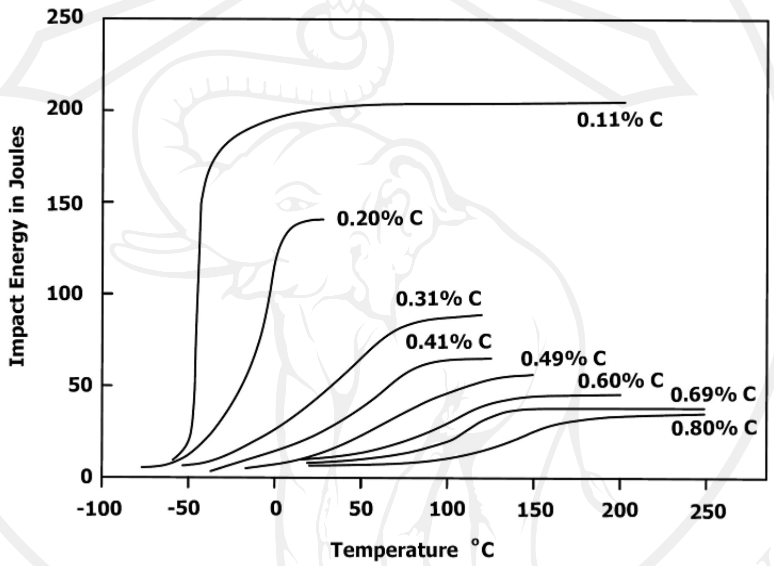
รูป ก-1 ตัวอย่างชิ้นงานที่เสียสภาพจากการทดสอบแรงดึง (ก) เสริมแรงด้วยเส้นใยไผ่ (ข) เสริมแรงด้วยเส้นใยไผ่ผสมท่อนาโนคาร์บอน



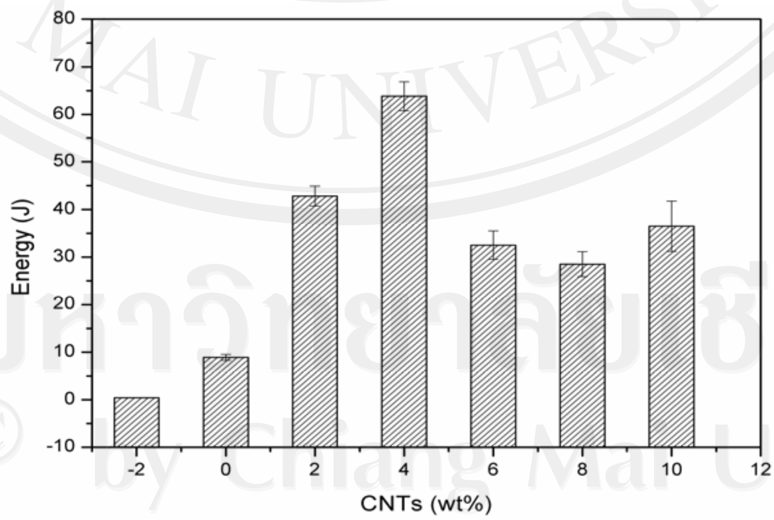
รูป ก-2 ตัวอย่างชิ้นงานที่เสียสภาพจากการทดสอบแรงกระแทก (ก) เสริมแรงด้วยเส้นใยไผ่ (ข) เสริมแรงด้วยเส้นใยไผ่ผสมท่อนาโนคาร์บอน

ภาคผนวก ข

เปรียบเทียบพลังงานความต้านทานแรงกระแทกของเหล็กและวัสดุผสมระหว่างอีพ็อกซีเรซินกับเส้นใยไผ่ผสมท่อนาโนคาร์บอนที่ได้จากการทดลอง



รูป ข-1 The Charpy V-notch ductile-brittle transition curves for several normalized irons and steels [41]



รูป ข-2 กราฟความสัมพันธ์ระหว่างค่าเปอร์เซ็นต์การยืดตัวกับสัดส่วนของท่อนาโนคาร์บอนของวัสดุผสม

ภาคผนวก ค

ผลงานวิจัยการดัดแปรเส้นใยไผ่ชนิดสั้น

The Influence of Alkaline Treatment on Tensile Properties of Short Bamboo (*Thyrsostachys Siamensis* Gamble) Fiber Reinforced Epoxy Resin Composites

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Abstract

In this work, the influence of alkaline treatment on tensile properties of short bamboo fiber reinforced epoxy resin composites was investigated. Sodium hydroxide (NaOH) was used as a treatment agent. To improve the ability of adhesion, bamboo fibers were treated in NaOH solution in different concentrations and soaking times. The treated fibers were then fabricated to composites via casting technique. Mechanical properties and microstructure of composites were determined using tensile testing and scanning electron microscope (SEM), respectively. From the results, it could be seen that the alkaline treatment can improve the fiber-matrix adhesion of composites which have effect to better mechanical properties of composites.

Keywords: Short bamboo fiber, Alkaline treatment, Epoxy composite, Tensile properties

Introduction

Researching on natural fiber reinforced composites is wildly interested in many industrial worlds nowadays. These industries are furniture, automotives, building construction, and etc. Since natural fiber exhibits unharmed properties to human and environment. Then, it is the interesting materials which use instead to conventional composite materials such as fiber glass. Besides, natural fiber also shows acceptable specific strength properties, low cost, low density, non-abrasivity, good thermal properties, enhanced energy recovery and especially, biodegradability. However, the hydrophilic is the disadvantage of natural fiber. Because of its high level of moisture absorption and poor wettability, the incompatibility between natural suitable chemical pre-treatment may be improve the internal adhesion of fiber. Alkaline treatment is a common method which use for cleaning, modifying and enhance interfacial adhesion between a natural fiber and a polymeric matrix. The treatment parameters for an optimal composite quality are still not clearly specified. Several authors mention different values of time, alkaline, concentration and duration to immerse the fiber. Many works are reviewed about the effect of alkaline treatment on properties of natural fibers [1-7]. In this research, bamboo fiber (*Thyrsostachys Siamensis* Gamble of in Thai Pai Luak) is use as a material to reinforce polymer matrix in epoxy composite. It is recognized as one of the most attractive

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Table 1 Mechanical properties of bamboo fiber

Types of fiber	Density (g/cm^3)	Tensile strength (MPa)	Young modulus (GPa)	Elongation at break (%)	References
Bamboo	1.16	610	46		[9]
Jute	1.3	393-773	26.5	1.5-1.8	[10]
Flax	1.5	343-1035	27.6	2.7-3.2	[10]
Cotton	1.5-1.6	287-597	5.5-12.6	7.0-8.0	[10]
Sisal	1.5	511-635	9.4-22.0	2.0-2.5	[10]

rapidly, thus it is easy to regenerate after cutting, and the bamboo fiber has relatively high strength compared with other natural fiber such as jute and cotton [8]. The mechanical properties of bamboo fibers are included in table 1.

Natural fiber especially plant fibers have an external surface which coated with waxy substances. This surface is not suitable for creating a strong bond with polymer matrix. Interfaces play an important role in the physical and mechanical properties of composites [11-12]. Hence, the treatment of fiber needed to improve the materials. In this study, the effect of alkaline treatment of short bamboo fiber reinforced epoxy composites on tensile properties was studied. Mechanical properties and microstructure of samples were investigated.

Experimental

The natural fiber/epoxy resin composites were fabricated by casting technique. Short bamboo fiber was used as reinforcement phase whereas epoxy resin was used as matrix phase. In this work, sodium hydroxide (NaOH) was used as treatment solution. Firstly, the bamboo fibers (*Thyrsostachys Siamensis* Gamble) were collected from Noonsombon Village, Roi-Et Province, Thailand. Bamboo fibers were then carefully extracted from the bundles by using pen knife. A diameter of fiber was in the range of 250-300 μm. Secondly, chemical treatment solution (NaOH 97%, Acilabscan Ar1171-P1KG) was prepared by dissolving in deionized water with different concentration of 0.25 M and 0.5 M this based on the following formula:

$$M = n/V \qquad (1)$$

where M, Molarity of a solution; n, number of mole of solute; V, volume of solution (dm^3)

To obtain the optimal condition, bamboo fibers was immerse in NaOH solution (0.25 M and 0.5 M) for different time, 60 min, 4 h and 8 h, respectively. Thereafter, fibers were rinse with deionized water until rinsed solution reached neutral (pH 7). The fibers were then dried at room temperature for 5 days. To fabricate composites, the fibers were then cut into 10 mm lengths and mixed with epoxy resin in the rubber mould in the dog-bone shape (Fig. 1) with a sample thickness of 1 mm. It is noted that mylar films were put at the upper and the lower of the samples in order to obtain a smooth surface.

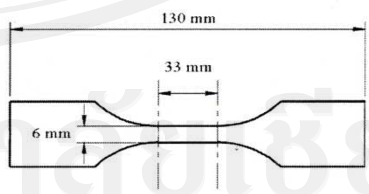


Fig. 1 The tensile test of composite samples.

Finally, the composite samples were left to settle at the room temperature for one day and then removed from the mould. Tensile strength of the samples was measured by the Hounsfield mechanical testing machine using a cross-head speed of 50 mm/min and 250 mm extensometer. The microstructure of composites samples were investigated by scanning electron microscope (SEM).

Results and Discussion

From the results, it can be seen that the removal of wax, fatty substance and lignin by alkaline treatment are successfully.

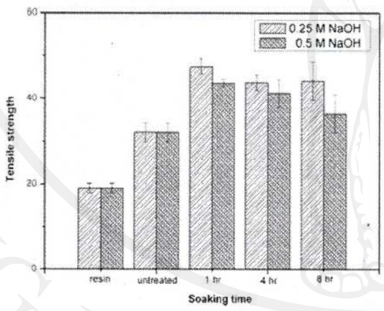


Fig. 2 Average tensile strength of short bamboo fiber reinforced epoxy composite with soaking time.

Colors of fibers were changed from brown to dark brown. Moreover, SEM micrographs (Fig. 4) confirm the effective of alkaline treatment which agree with other previous work [13]. Fig. 2 shows the results of the tensile strength at different soaking times for two different alkaline concentrations. It was sound that the tensile strength exhibits the same trend with different concentration treatment. The optimal condition is at soaking time of 1 h and 0.25 M concentration.

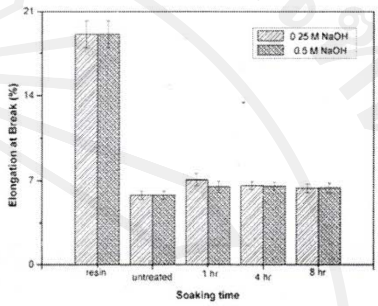
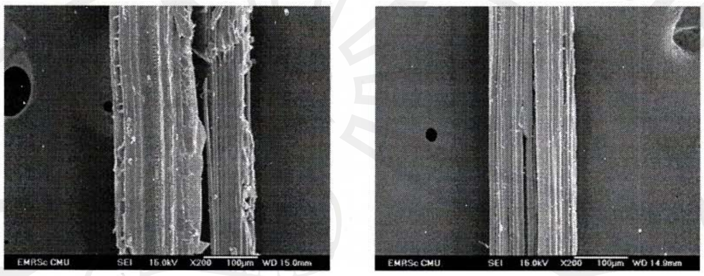


Fig. 3 Average elongation percentage at break of short bamboo fiber reinforced epoxy composite with soaking time.

The enhancement in tensile strength in alkaline treated (for 0.25 M alkaline concentration with 1 h soaking time) fiber composites is attributed to the improvement of wetting of alkaline treated fiber with the matrix [14]. Therefore, it can be said that the alkaline treatment can remove impurities and waxy substance from fiber surface. Besides, the rougher surface also found after alkalization. These make the mechanical interlocking which affect to good quality of interface bonding. Since, the size of fiber in the matrix becomes smaller, the extent of stress concentration derived from the fiber will decrease, which leads to increase in the strength [15]. Increasing of alkaline concentration is expected to show a positive influence on the tensile strength of composite. But the experiment demonstrates that the strength decrease with increasing of alkaline concentration. This may be due to the damage of fiber structure in higher alkaline concentration [2], agree with Mwai-kambo and Ausell [16], a very high concentration of alkaline solution would certainly damage the fiber and consequently reduce the tensile strength of fiber and also their



(a) (b)

Fig. 4 SEM surface studies of (a) untreated (b) NaOH-treated short bamboo fibers.

composites. From the results may be occur the combining effect of the improvement of adhesion interface and the damage of fiber after alkalization process.

Moreover, the elongation of break (ε) of composite was not affected significantly by the alkaline concentrations and soaking times even the diameter and aspect ratio was increased shows in Fig. 3. The percent elongation at break of the composites is lower than that of the matrix. This could be affected of low fracture strain and the poor adhesion between the matrix and the fibers [11]. SEM micrographs of fiber were shown in Fig. 4. It can be seen that bamboo fiber (Fig. 4(a)) contains impurities, wax, fatty substances, hemicelluloses, and lignin [17].

The fiber surfaces are extremely heterogeneous, with smooth and rough portions in the same fiber. It confirms that the role of the treatment is mainly to remove these impurities of the natural bamboo fiber, thus improving their wettability. As can be seen in Fig. 4(b), fiber treatment removed fatty-deposits, hemicelluloses and lignin leading to the formation of a rough surface, resulting in mechanical anchorage and reduced pullout and gaps between the fiber and matrix in composition materials. Similar results were observed by Bismarck et.al. [18] who reported that alkaline treatment resulted in a higher amount of cellulose exposed on the fiber surface, thereby increasing the number of possible reaction sites.

Fig. 5 SEM micrographs for untreated bamboo fiber reinforced epoxy composite fracture after tensile loading.

Fig. 5 shows the SEM micrographs for untreated bamboo fiber epoxy composite facture after tensile loading. The average value of tensile strength for this condition is 32.15 MPa. From the figure it is shown that a hole is the fiber was pulled out from the matrix when stress is applied, and a small gap has occurred between a fiber and matrix. Although the composites in the presence of a small gap, which may due to the effect of the processing condition, generally that composite specimen shows good interfacial adhesion [19]. SEM micrographs for the composites after alkaline treatment are shown in Fig. 6(a) and 6b for 300X

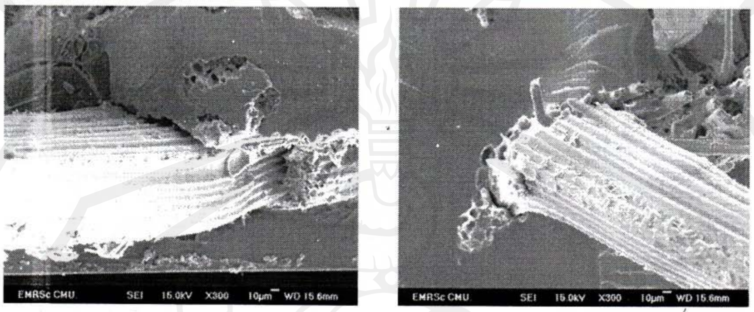


Fig. 6 SEM micrographs for treated (a) 0.25 M NaOH (b) 0.5 M NaOH bamboo fiber reinforced epoxy composite fracture after tensile loading.

magnifications. Fig. 6(a) shows the SEM micrograph for treated 0.25 M NaOH bamboo fiber reinforced epoxy composite fracture after tensile loading. The highest value of tensile strength is 47.49 MPa. The figure shows the interfacial adhesion between fiber/matrix remain in good performance, indicated by the clean fiber surface and contour of matrix close to the fiber surface. Moreover, after 1 h soaking time, the tensile strength were decreased. It may be due to the damage of fibers after alkaline treatment. Fig. 6(b) shows the SEM micrographs for treated 0.5 M NaOH bamboo fiber reinforced epoxy composite fractured after tensile loading. Generally, it was seen that the interfacial bonding between fiber and matrix shows good performance. The surface of fiber has cleaner than the untreated fiber and it created interlocking mechanism with the surface of matrix. The better adhesion was shown for the increasing of the alkaline concentrations and soaking times. But this phenomenon is not sufficient to enhance the tensile strength for the samples at high alkaline concentration and longer soaking time because the fiber was damage which could lead to this inferiority in strength property.

Conclusion

The influence of fiber treatment by mercerization (alkaline) on the tensile properties of short bamboo fiber reinforced epoxy composites was analyzed. The alkaline treatment has significantly improved the tensile properties of short bamboo fiber reinforced epoxy composites particularly for tensile strength but the elongation at break of the composite was not affected significantly by the alkaline treatment (alkaline concentration and soaking time). The optimum strength obtained from 0.25 M NaOH with 1 h soaking time. The hydrophilic nature of short bamboo fiber has been reduced due to this treatment and therefore has increased the interfacial bonding between matrix and fibers.

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ประวัติผู้เขียน

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