Comparative investigation on physical and mechanical properties of water hyacinth and cattail fiber reinforced epoxy hybrid composites

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Abstract. In this research, the study to investigate and compare the physical and mechanical properties of water hyacinth and cattail fiber reinforced epoxy hybrid composites. The composites were fabricated by hand lay-up process. The effect of investigation was analyzed via water absorption, microstructure, tensile properties, flexural properties and impact strength tests for total fiber contents, 15 wt% and different water hyacinth-cattail fiber ratios (10/0, 8/2, 6/4, 4/6, 2/8 and 0/10). The results showed that the addition of water hyacinth and cattail fiber in epoxy, improves tensile properties, flexural properties and impact properties, but decrease water absorption**.** The analysis of the microstructure found that surface fracture behavior and void between the fiber and matrix of the composites using scanning electron microscope **(**SEM**).**

1. Introduction

Composite reinforced with natural fibers have become the new materials that are used as high strength and stiffness, nature material and environmental 'friendliness' [1]. In addition, they are recyclable, renewable and low cost [2]. However, in this study, a water hyacinth and cattail are used as a material to reinforce a polymer matrix in epoxy hybrid composites. Water hyacinth are very useful natural fiber to be used as a reinforcement in composite material due to their appealing characteristics: cellulose has a small diameter and high contents [3]. Recently, studies about modified water hyacinth fibers composites on improving of mechanical properties have been reported [4]. Among the bio fiber, cattail fibers is nowadays widely used in many industrial applications [5]. This research can be applied of cattail fibers as a material for product of different density composites boards, which can be used in the packaging, construction and lightweight materials [5]. Therefore, in this work, the study to the influence of water hyacinth hybridization with cattail composites were compared in terms of physical, mechanical properties and scanning electron microscopy (SEM).

2. Materials and Methods

2.1. Materials

The nature fiber is a water hyacinth and cattail fiber from Rajabhat Maha Saraham University, Maha Sarakham province, Thailand. The age of both type fibers are around 1-2 years and it used to range in diameter between 200-300 µm. Epoxy resin and hardener and a density of 1.18 g/cm^3 was used as the matrix.

2.2. Composite fabrication

Fabric water hyacinth and cattail fibers were reinforced in epoxy to prepare the hybrid composites. Firstly, both fibers were extracted from the plants with a pen knife. Secondly, the fibers 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 hours [6]. Thereafter, the fibers are washed with water until natural (pH7). The fibers are then dried to leave it at room temperature for 7 days. Later, both fibers were milled and sieved to keep particles between 9 and 10 mesh. The two fiber contents (15% by weight) were prepared using the different water hyacinth and cattail fiber ratios (10/0, 8/2, 6/4, 4/6, 2/8 and 0/10). A matrix was created by the combination of epoxy resin and hardener in the ratio 10:1 by weight [7]. The mixture is then poured into the rubber mold. It was executed according to the ASTM test (ASTM D570 for water absorption, ASTM D680 type 1 for tensile test, ASTM D790 for flexural test and ASTM D256 for impact test). After that, Maylar films were put at the top and bottom of the specimen 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. After that, take a sample to test the physical and mechanical properties that fabricated five specimens of each testing and microstructure of the tested composite samples was analyzed by scanning electron microscope (SEM). Finally, all results are specific as the mean ± SD. The statistical analysis was performed with One-way ANOVA with considered confidence level significant differences at the data 95 %. P-value is an alpha of 0.05 is used as the cut off for significance.

Table 1. Mechanical properties of composites.

Type composites *(Wate rhyacinth: cattail)*	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Strength (kJ/m^2)
Epoxy Resin	1.99±0.67	30.83±14.88	32.71±3.38	267.33±0.57	0.35±0.07
10:0	13.41±5.79	421.50±115.18	30.21±5.24	374.57±106.16	1.52±0.04
8:2	11.79±0.62	313.33±98.00	30.25±2.94	529.33±117.03	1.35±0.16
6:4	14.60±3.23	384.33±5.20	33.55±0.77	613.03±34.21	1.49±0.01
4:6	17.16±1.85	562.66±112.80	32.49±3.74	670.67±29.99	1.66±0.03
2:8	17.07±5.10	496.00±121.68	29.78±2.43	610.05±89.43	1.67±0.02
0:10	16.46±3.20	429.83±67.76	42.69±9.25	753.66±137.96	1.43±0.01
P-value	0.01*	0.00*	0.05*	0.00*	0.00*

Where, * is significantly difference at p<0.05 (The value of p <0.05 is about the statistical significance of test.)

3. Results and discussion

3.1. Tensile test result

The tensile strength and modulus results of hybrid composites as shown are figure 1. In addition, a detailed statistical analysis is available, as shown in table 1. The results showed that there was statistically significant variation between the mean tensile strength and modulus with ratios for both fibers ($p<0.05$). From figure 1, it can be observed that both tensile strength and modulus of the all fiber ratios is higher than pure epoxy resin. The composites at 4/6 water hyacinth/cattail fiber ratios shows higher tensile strength and modulus the other fiber ratios, which it shows the highest value of tensile strength and modulus is 17.16 MPa and 562.66 MPa respectively. A higher tensile property of composites may be due to the good compatibility between the both fiber in different ratios. Improvements in mechanical properties are often associated with a combination of compatible material [8]. According to studies of Baiardo *et al.* [9], it was found that the mechanical properties of composites materials reinforced with short fibers that are depended on (i) the nature properties of the fiber and the matrix, (ii) aspect ratio of fiber and matrix, volume, distribution lengthwise and orientation of the fibers and (iii) effective adhesion between fiber and matrix which acts to transfer loads in composites.

3.2. Flexural test result

The flexural strength and modulus of epoxy resin composites reinforce with varies in ratios of the fiber as shown is figure 2. While, table 1 shows the analysis of variance (ANOVA) of the flexural properties. From the results, it was found that the P-value less than 0.05 had statistically significant variation between in flexural strength and modulus form composites with two fibers in different ratios. It was observed that flexural strength and modulus of composites increased following by the ratios of cattail. Highest flexural properties were shown by 0/10 fiber ratios (42.69 MPa for flexural strength and 753.66 MPa for flexural modulus). Improvement in the flexural properties of the water hyacinth/cattail hybrid composites may be due to similar cause in the results of tensile test. On the other hand, flexural properties decreased at 2/8 fiber ratios, which can be caused by the possibility of increasing the area of voids between fiber and matrix within composites. According to Khalil *et al.* [10] showed that the weak bonding between fiber and matrix, causing poor flexural properties.

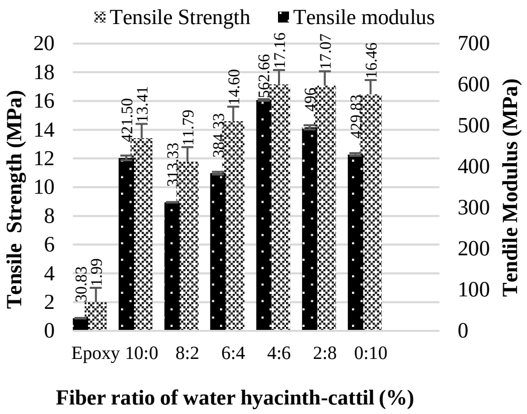

Figure 1. Tensile properties of different fiber ratios.

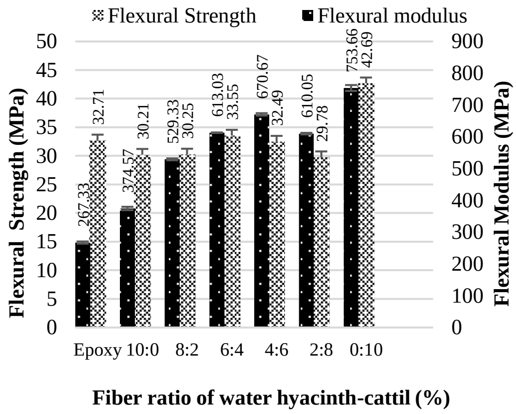

Figure 2. Flexural properties of different fiber ratios.

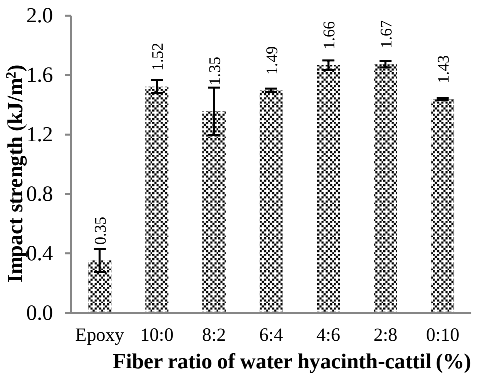

Figure 3. Impact strength of different fiber ratios.

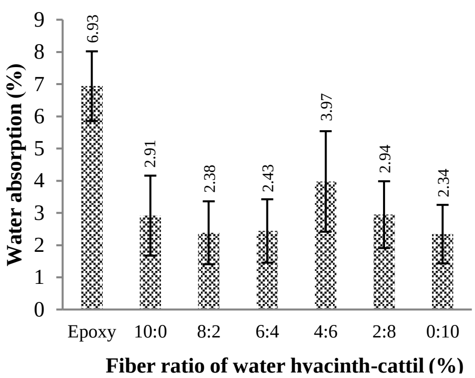

Figure 4. Water absorption of different fiber ratios.

3.3. Impact test result

Figure 3 shows the impact strength of water hyacinth/cattail hybrid composites. At the same time, a detailed statistical analysis was conducted, as shown in table 1. The statistically significant difference between the mean value of impact strength of hybrid composites were determined by P-value ($p<0.05$). At a fiber ratio of 4/6 and 2/8, the maximum impact strength of the hybrid composites was 1.66 kJ/m^2 and 1.67 kJ/m^2 respectively. The impact performance of composites depends on many factors such as the failure of the matrix and pull out fibers [11]. According to Mishra *et al.* [12] showed that the between fiber and matrix with good adhesion also determines fracture resistance during impact test.

3.4. Water Absorption result

The water absorption on capacity of hybrid composites after 30 mm/min of immersion is shown in figure 4. The figure showed that after 30 min of immersion, it was observed that all fiber ratios decreased the water uptake of hybrid composites, but while epoxy resin has the highest water absorption, it is consistent with the result of mechanical tests. According to Sair *et al.* [13] showed that the ability to water uptake is a factor that result in decrease mechanical properties of the composites, On the other hand, according to a study by Ruksakulpiwat *et al.* [14], the decrease of water uptake of bio-based composites can be explained by several reasons: (i) greater adhesion bonding between fibers, (ii) better water relations of the matrix compared to the fiber and (iii) inhibition of water diffusion through the matrix due to the intertwining of fibers caused by higher fiber content.

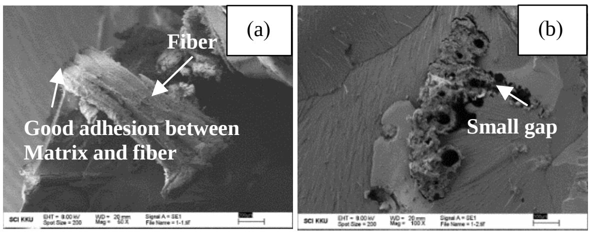

Figure 5. SEM micrographs of hybrid composites sample after tensile testing. (a) 4/6 fiber ratios (b) 8/2 fiber ratios.

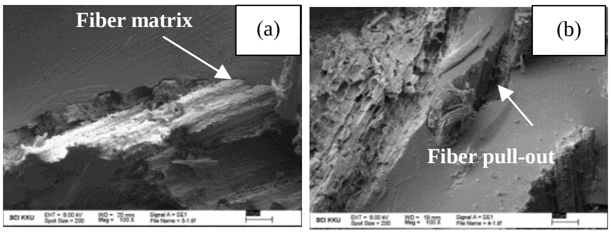

Figure 6. SEM micrographs of hybrid composites sample after flexural testing. (a) 0/10 fiber ratios (b) 8/2 fiber ratios.

3.5. SEM morphology

Figure 5 (a) shows the good properties for 4/6 fiber ratios. Figure 5 (b) shows the small gab around the fibers, which affected the ability of adhesion between matrix and fibers is poor. Incomplete wettability or bonding between matrix and fibers during the fabrication of hybrid composites probably cause a small gab [15]. Figure 6 (a) shows the 0/10 fiber ratios have a best adhesion between matrix and fibers. Thus, reinforcement is strongly adhesion to the matrix if they have high strength and stiffness is to be imparted to the composites clearly [16]. Figure 6 (b) shows the images is clear that there is virtually poor interfacial bonding between the fiber and matrix [17]. The fibers/epoxy is probably the case of the poor flexural strength.

4. Conclusion

The effect of fiber ratios on physical and mechanical properties of epoxy hybrid composites reinforced by the fibers of water hyacinth and cattail were investigated. Six level of fiber ratios (10/0, 8/2, 6/4, 4/6, 2/8 and 0/10) were considered. Based on the results, the following conclusions are drawn; The comparison of tensile properties showed that 4/6 fiber ratios, which it shows the maximum value of tensile properties. The flexural properties of 0/10 fiber ratios show highest value compared to other fiber ratios reinforced hybrid composites. The impact strength reveal that 4/6 and 2/8 fiber ratios can resist higher impact load than other fiber ratios. Water absorption results showed that both type of fibers have a low water absorption rate, which reduces the water absorption of hybrid material. Study on the morphology of composites shows the fiber pull out, interfacial characteristic, fiber failure and internal structures of the surfaces are clearly observed. It is suggested that these both fibers reinforced epoxy hybrid composites can be used as an alternate material for materials reinforced with synthetic fiber.

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