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Influence of Fibre Volume Fraction and Vacuum Pressure on the Flexural Properties of Sugar Palm Frond Fibre Reinforced Polyester Composites

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Abstract: Synthetic fibre has been used widely in manufacturing industries, especially glass fibre because of low-cost and high strength. Possibility of substituting glass fibre with natural fibre where in this study sugar palm frond fibre has been found to have a great potential to be used in composite materials. This paper presented a study on flexural properties of sugar palm frond fibre reinforced polyester composites. It aimed to investigate the influence of different fibre volume loading (5%, 10%, 15%) and various vacuum pressures (5psi, 10psi, 15psi) on the flexural strength. Untreated fibre obtained from the fronds of the sugar palm trees was used as reinforcement in polyester resin. The composite was fabricated by using vacuum bagging technique. Based on the result, it was found that the fibre volume fraction of 5% and 15psi of vacuum pressures gave maximum value in flexural strength and flexural modulus. The results indicate that the decreasing the fibre volume and increasing the vacuum pressure has a better interfacial bonding between its fibre and matrix. From the ANOVA analysis, the result shown there is a significant effect of fibre volume fraction and vacuum pressures on the flexural properties.

Keywords: Sugar palm fibre, Flexural properties, Fibre volume fraction, Vacuum pressure

INTRODUCTION

Natural fibre reinforced polymer composites have raised great interests among player in composites manufacturer in recent years due to the considerations of developing an environmental friendly material, and partly reducing the dependency on glass fibre. Moreover, many studies focused in developing natural fibres as raw material have been done and reported, such as palm, kenaf, coconut coir, and many others that have potential o be used as reinforcement materials. Sugar palm fibre is one of natural fibres that abundantly available from palm sugar tree. Since the last decade, it is widely used for many applications like roof, rope, water filter, and sound proof in recording studio (Bachtiar *et. al.,* 2008) Sugar-palm (*Arenga Pinnata* or *Arenga Saccharif-era*) trees are found growing productively in many tropical countries such as Indonesia, Malaysia and Papua New Guinea.

There are many factors that can influence the performance of natural fibre reinforced composites. Apart from the hydrophilic nature of fibre, the properties of the natural fibre reinforced composites can also be influenced by fibre content / amount of filler. In general, high fibre content is required to achieve high performance of the composites. Therefore, the effect of fibre content on the properties of natural fibre reinforced composites is particularly significance. It is often observed that the increase in fibre loading leads to an increase in tensile properties (Ahmad *et. al.,* 2006) Another important factor that significantly influences the properties and interfacial characteristics of the composites is the processing parameters used. Suitable processing techniques and parameters must be carefully selected in order to yield the optimum composite products.

This presented paper looks at the opportunity to utilise sugar palm frond fibres as reinforcement in natural fibre composites. Most of the recent studies, sugar palm fibre that been used as a reinforcement mostly is the hairy black fibres that cover the trunk of the tree. The fibre is known by several different names including sugar palm fibre, Ijuk, Gomutu, and Gomuti. The aims of this paper is to determine the flexural properties of sugar palm fibre reinforced polyester composites and to explore the suitability to use the fibres as reinforcement in composites. Therefore, the objective of this study is to investigate the effects of fibre loading and process parameters on flexural properties of sugar palm frond fibre reinforced polyester composites.

MATERIALS AND METHODS

Sugar palm frond as shown in Fig. 1 was obtained from Kampung Senibong, Johor Bahru. The frond was obtained from matured sugar palm trees. Sugar palm frond fibre was extracted and cut at the average width of 10 mm in length. Fig. 2 showed the sugar palm frond fibre.

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Fig. 1: Sugar palm frond.

Fig. 2: Sugar palm frond fibre.

The chopped sugar palm subsequently washed by using reverse osmosis water to remove the dirt and later dried in the sunlight until all the moisture is removed from sugar palm frond fibres. No chemical treatment has been made to the sugar palm frond fibres in an attempt to simulate the original strength of fibres. Polyester resin is obtained from Luxchem polymer under the trade name of Polymal 820-1-WPT(P). It appears as clear yellow colour liquid with viscosity of 400 cps and specific gravity of 1.13.

The composites with 5%, 10% and 15% of fibre volume fraction were fabricated using vacuum bagging technique with size mould of 200 mm (length, *L*) × 150 mm (width, *W*) × 3 mm (thickness, *T*). Initially, polyester resin and hardener were mixed with ratio 200 : 2 to form a matrix. Then, fibres were spread into mould and covered with the matrix. The composites were compressed by using varies vacuum pressure at 5 psi , 10 psi and 15 psi until thickness of 3 mm was achieved. The impregnation time is kept constant at 10 min. The curing time was about 24 hours applied near room temperature (25-30°C). Finally, composites plates were cut into the flexural specimen based on the ASTM standard D790.

The flexural test was performed at the Fibre and Biocomposite Development Centre (FIDEC) at Olak Lempit, Banting. Flexural test of the specimens has been carried out at the room temperature with a constant cross-head rate of 10 mm/min using universal testing machine type Gotech model. The load cell that has been chosen is 5 tons. Five specimens were tested for each various fibre loading and vacuum pressure, and the average value was obtained using Gotech software. Result of the flexural properties was then been analyze by using analysis of variance (ANOVA). The purpose of this ANOVA analysis is to investigate the design parameters significantly affect the quality characteristic of a product or a process.

RESULT AND DISCUSSION

The result of flexural strength and flexural modulus of sugar palm frond composites with varying fibre content at different vacuum pressures is presented in Fig. 3 and Fig. 4. From the result obtained , 5% of fibre volume fraction and 15psi of vacuum pressures is identified as optimal fibre content and vacuum pressure because it given the highest flexural strength at 85.9 MPa. The minimum value was 15% of fibre content and 5psi of vacuum pressures at 37.8 MPa for flexural strength. It can be seen that the increasing of fibre volume fraction in composites will decreasing the flexural properties. This can attributed to many factors such as an incompatibility between matrix and fibres, improper manufacturing process, fibre degradation and others. Meanwhile, as the vacuum pressures increased the tensile strength is also increased.

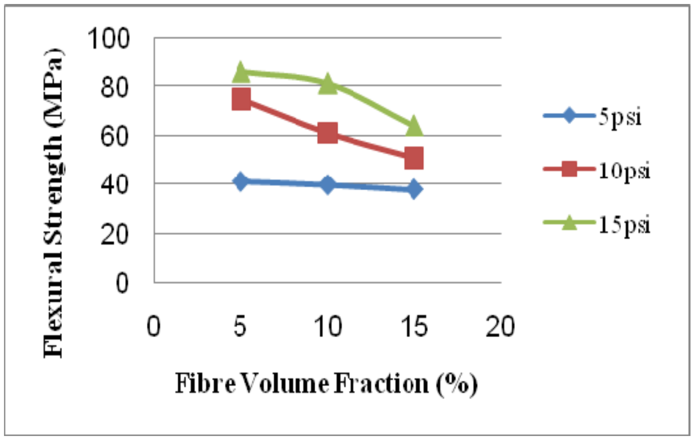

Fig. 3: The flexural strength of different fibre volume faction at different vacuum pressures.

Modulus of elasticity is referring to the material's stiffness. It can be determined from slope of a stress-strain produced from flexural test. The maximum value for flexural modulus was 5% of fibre volume fraction and 15psi of vacuum pressures at 1879.6 MPa and minimum value was 15% of fibre volume fraction and 5psi of vacuum pressures at 872.5 MPa. The decreasing of modulus young with respect of decreasing volume fraction of fibre is poor interfacial adhesion between the surface of fibres and matrix. The brittleness of composites is also contributed to low mechanical strength because higher fibres contain higher possibilities of the fibres to sustain higher load. This study proves with the finding by Sastra *et al.*, (2005) that decreasing fibre volume fraction gives the highest flexural strength and modulus young.

The similar result indicates by Abral *et al.*, (2011) showed that the highest mechanical properties of composites were recorded for the highest vacuum pressures. It also stated that the increasing of mechanical properties strength after vacuum process may be affected by improvement of stress shearing into fibres. Medina *et. al.*, (2009) reported that above certain value of pressure, there was a decrease in mechanical properties of the composites due to the damage of fibre structure. It also was found that many polyester resins enclosed strongly on fibre surface of the composites made under vacuum pressures. However the advantages of using vacuum technology are to allow a reduction of the press time to a minimum without decreasing the performance of the cured materials.

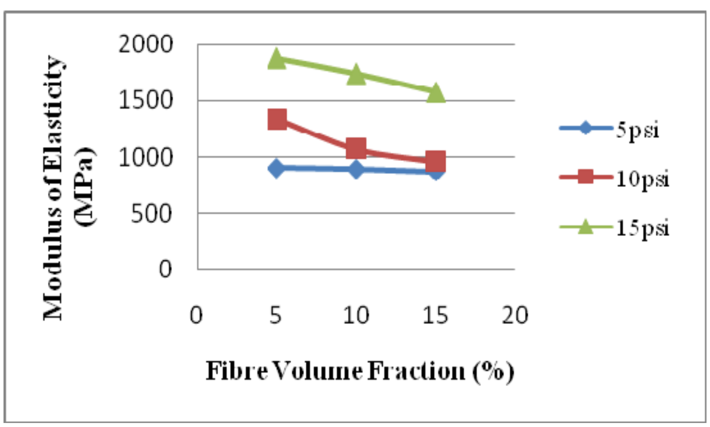

Fig. 4: The flexural modulus of different fibre volume fraction at different vacuum pressures.

An analysis of variance of the data with the flexural strength in three different fibre volume fractions and three different vacuum pressures was performed, with the objective of analyzing the influence of fibre loading and vacuum pressure. For this study two away analysis of variance is performed because it involve two independent variable. Table 3 lists the mean and standard deviation from three fibre volume fraction in three vacuum pressure.

Table 1: Mean and standard deviation from three fibre volume fraction in three vacuum pressure.

Dependent Variable: flexural				
volume	pressure	Mean	Std. Deviation	N
5.00	5.00	33.0000	4.63681	5
	10.00	47.4000	21.00714	5
	15.00	89.0000	14.74788	5
	Total	56.4667	28.25614	15
10.00	5.00	54.4000	14.79189	5
	10.00	37.2000	23.96247	5
	15.00	81.6000	24.19297	5
	Total	57.7333	27.41862	15
15.00	5.00	47.0000	8.91628	5
	10.00	51.0000	7.14143	5
	15.00	46.8000	11.88276	5
	Total	48.2667	9.03538	15
Total	5.00	44.8000	13.25680	15
	10.00	45.2000	18.47469	15
	15.00	72.4667	25.14775	15
	Total	54.1556	23.17812	45

Table 2 show the results of the analysis of variance with the flexural strength in varies fibre volume fraction and vacuum pressure.

Table 2 : Analysis of variance with the flexural strength in varies fibre volume fraction and vacuum pressure.

Dependent Variable: flexural					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14316.711[a]	8	1789.589	6.912	.000
Intercept	131977.089	1	131977.089	509.717	.000
volume	792.311	2	396.156	1.530	.230
pressure	7545.378	2	3772.689	14.571	.000
volume * pressure	5979.022	4	1494.756	5.773	.001
Error	9321.200	36	258.922		
Total	155615.000	45			
Corrected Total	23637.911	44			
a. R Squared = .606 (Adjusted R Squared = .518)					

Flexural strength with 5% fibre loading and 15psi vacuum pressure achieve the highest mean score (mean = 89.). As indicated in Table 2, because the significant value of fibre volume fraction (0.230) is more than the threshold value (0.05), it can be concluded that the influence of fibre volume fraction alone does not effect the flexural strength. The significant values of vacuum pressure (0.00) and the interaction between the two factors fibre volume fraction and vacuum pressure (0.001) are less than threshold value (0.05), leading to the conclusion that vacuum pressure and the combination of vacuum pressure and fibre volume fraction do influence flexural properties of sugar palm frond fibre reinforced polyester composites.

Conclusion

Flexural test was performed on sugar palm frond fibre reinforced polyester composites. The influence of various fibre volume fraction and vacuum pressure were investigated. Based on the results obtained, the following conclusions can be drawn:

a. Flexural strength for 5% fibre volume fraction and 15 psi vacuum pressure shown the highest value among the others.

b. In the analysis of variance , the most influencing parameters were vacuum pressure and the interaction effect of fibre volume fraction and vacuum pressure also playing a role to increase the flexural properties.

c. Flexural strength results showed that sugar palm frond fibre has the average flexural stress which is 40.00 MPa to 88.00 MPa. The value is slightly higher when compared to the chopped random sugar palm fibre also call ijuk fibre (64.71 MPa) done by Sastra *et. al.,* (2006) and Leman *et. al.,* (2008) in their studies also showed lower flexural stress compared to sugar palm frond fibre.

d. The result showed that sugar palm frond fibre has a potential to be used as a reinforcement same like sugar palm fibre (ijuk fibre).

e. The results confirmed that more studies are needed to determine the beneficial and cost effective applications of the sugar palm frond fibre in composites. It is expected that with proper treatments, the flexural properties of the sugar palm frond fibre and the adhesion of sugar palm fibre-polyester resin can be improved.

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