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Mechanical Properties of Short Random Oil Palm Fibre Reinforced Epoxy Composites
(Ciri-ciri Mekanikal Gentian Pendek Secara Rawak Kelapa Sawit Bertetulang Komposit Epoksi)

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ABSTRACT

This paper presents the study of mechanical properties of short random oil palm fibre reinforced epoxy (OPF/epoxy) composites. Empty fruit bunch (EFB) was selected as the fibre and epoxy as the matrix. Composite plate with four different volume fractions of oil palm fibre was fabricated, (5 vol%, 10 vol%, 15 vol% and 20 vol%). The fabrication was made by hand-lay up techniques. The tensile and flexural properties showed a decreasing trend as the fibre loading was increased. The highest tensile properties was obtained for the composite with fibre loading of 5 vol% and there were no significant effect for addition of more than 5 vol% to the flexural properties. Interaction between fibre and matrix was observed from the scanning electron microscope (SEM) micrograph.

Keywords: Empty fruit bunch; epoxy; flexural properties; tensile properties

ABSTRAK

Kertas ini membentangkan kajian tentang ciri mekanikal gentian pendek secara rawak kelapa sawit bertetulang komposit epoksi (OPF/epoxy). Tandan buah kosong (EFB) dipilih sebagai gentian dan epoksi sebagai matriks. Plat komposit dengan empat perbezaan pecahan isipadu gentian kelapa sawit telah difabrikasi iaitu 5 isi padu %, 10 isi padu %, 15 isi padu % dan 20 isipadu %. Fabrikasi telah dibuat dengan menggunakan teknik bengkalai dengan tangan. Ciri-ciri kekuatan dan kelenturan menunjukkan trend penurunan apabila kandungan gentian bertambah. Ciri-ciri kekuatan tertinggi terdapat pada komposit dengan kandungan gentian sebanyak 5 isi padu % manakala penambahan lebih daripada 5 isipadu % pada ciri-ciri kelenturan tidak membawa sebarang kesan yang signifikan. Hubungan antara gentian dan matriks di perhatikan melalui mikrograf SEM.

Kata kunci: Ciri-ciri kelenturan; ciri-ciri ketegangan; epoksi; tandan buah kosong

INTRODUCTION

There has been a growing interest in utilizing natural fibres as reinforcements in polymer composite for making low cost construction materials in recent years. Natural fibres are prospective reinforcing materials and their use until now have been more traditional than technical. They have long served many useful purposes but the application of the material for the utilization of natural fibres as reinforcement in polymer matrix took place quite recently (Joseph et al. 1999). Many studies had been carried out on natural fibre likes kenaf, bamboo, jute, hemp, coir, sugar palm and oil palm (Arib et al. 2006; Khairiah & Khairul 2006; Lee et al. 2005; Rozman et al. 2003; Sastra et al. 2005). The advantages of these natural resources are low weight, low cost, low density, high toughness, acceptable specific strength, enhanced energy recovery, recyclability and biodegradability (Lee et al. 2005; Myrtha et al. 2008; Sastra et al. 2005). Natural fibre can be divided into four different types which are leaf, bast, fruit and seed (Khairiah & Khairul 2006; Wollerdorfer & Bader 1998).

The major source of edible oil is oil palm (*Elaeis guineensis*) which is extracted from its fruits. One of the significant problems in the palm fruit processing is managing of the wastes generated during the processes. It was estimated that more than two million tonnes (dry weight) of extracted oil palm fibre is generated annually in Malaysia (Tan et al. 2007). Currently, there are many studies on the incorporation of empty fruit bunch (EFB) into polymers to gain a cost reduction and reinforcement by various workers. Ridzuan et al. (2002) reported that it is possible to produce medium density fibreboard (MDF) from EFB fibre and can improve the MDF performance by a pre-treatment to remove the residual oil. Rozman et al. (2004) stated that the employment of EFB in mat form has produced polyurethane-empty fruit bunch (PU-EFB) composites with acceptable properties where composite with isocyanate treated fibres have a superior tensile and flexural properties than those without treatment. It is found that highest shore D hardness, impact and flexural strengths and better water resistance are exhibited in biocomposite board with blending ratio of 35:65 of PU matrix to EFB fibres (Khairiah & Khairul 2006). According to Rozman et al. (2001), there was a reduction of flexural and tensile strengths from the incorporation of EFB and glass fibre (GF) into polypropylene (PP) matrix. Kalam et al. (2005) found that increasing fibre volume ratio from 35 vol% to 55 vol% for oil palm fruit bunch fibre (OPFBF)/epoxy composite reduced the tensile strength of the composite and increased the Young's modulus. Composite of *Arenga pinnata* fibre reinforced epoxy showed that the 10 wt.% woven roving fibre has the highest value of flexural strength test (Sastra et al. 2005). Sapuan et al. (2006) has studied the mechanical properties of woven banana fibre reinforced epoxy composites and found that the composites can be used for the household utilities. Therefore, the purpose of this work is to study and evaluate the tensile and flexural properties of short random oil palm fibre reinforced epoxy (OPF/epoxy) composites. The composites were fabricated using hand lay up techniques and four different ratios were prepared.

MATERIALS & METHODS

MATERIALS

Oil palm empty fruit bunch (OPEFB) fibre was used and obtained from the Malaysian Palm Oil Board in Bangi, Selangor, Malaysia. The OPEFB were chopped using grinder model Retsch into 10 to 20 mm of fibre length. Epoxy resin purchased from Berjaya Bintang Timur Sdn. Bhd., Kuala Lumpur, Malaysia, with density of 1.15 g/cm^3 was used as the matrix. The properties of the OPEFB and epoxy are given in Table 1.

TABLE 1. Properties of raw material

	OPEFB	Epoxy
Diameter (μm)	250 – 610	-
Moisture content (%)	2.2 - 9.5	-
Tensile strength (MPa)	71	63
Young's modulus (MPa)	1703	1371
Elongation at break (%)	11	5.8
Flexural strength (MPa)	-	105
Flexural modulus (MPa)	-	3547

METHODS

The composites with fibre loading 5%, 10%, 15% and 20% of volume fraction were fabricated using hand lay up technique with size mould of 200 mm (length, *L*) × 150 mm (width, *W*) × 3 mm (thickness, *T*). Initially, epoxy and hardener were mixed with ratio 4:1 to form a matrix. Then, fibres were spread into mould and covered with the matrix. The composites were compressed until thickness of 3 mm was achieved. The curing time was about 24 hours applied near room temperature (25-30°C). Finally, composites plates were cut into the tensile and flexural specimens based on ASTM standard D638 and D790, respectively (Figure 1).

RESULTS AND DISCUSSION

TENSILE PROPERTIES OF OPF/EPOXY COMPOSITES

Figure 2 shows that the tensile strength of pure epoxy is much higher than the reinforced composites. There were not much difference from 5 vol% to 20 vol%. There were about 21% difference from the lowest to the highest value of tensile strength in average. The highest tensile strength for OPF/epoxy composites is obtained at 5 vol% with value of 29.9 MPa, in average. From the study carried out by Kalam et al. (2005), the tensile strength for OPFBF/epoxy composites at 35 vol% is 47.8 MPa and for OPFBF/epoxy composites at 55 vol% is 46.1 MPa. The highest tensile strength in this study is lower than both results of volume fraction reported by Kalam et al. (2005).

For this experiment, it is shown that the chopped fibre distribution in epoxy is random, so, the fibre could not hold the load when matrix was transferred. Doan

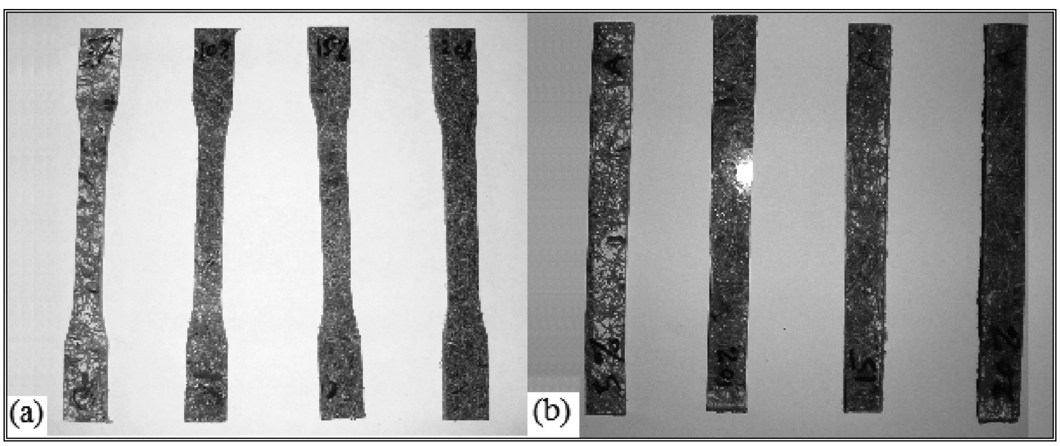

FIGURE 1. Specimens for (a) tensile test and (b) flexural test

et al. (2006) stated that fibre length plays an important role in the mechanical performance of fibre reinforced composites. Arib et al. (2006) compared the experimental and theoretical tensile strengths for pineapple leaf fibre reinforced polypropylene composites and found that the equation for rule of mixture fails to provide a good fit, and the discrepancy increases with the increase in fibre volume fraction. The fibre is not perfectly aligned and the presence of voids in the composites may also be the factor contributing to the lower experimental value.

The Young's modulus value of short random oil palm fibre reinforced epoxy composites is shown in Figure 3. It shows that the Young's modulus of 5 vol% was higher than 0 vol% which is pure epoxy but it was getting lower when the fibre content was increased. It can be seen that the optimum volume fraction for the composites is found to be at the 5 vol% of fibre loading. This maybe due to the fact that the load for fibre is low than the load for matrix itself. More fibre pull out occured as the fibre loading is increased. It can be seen from the SEM photograph for fibre with 15 vol% in Figure 4.

From Figure 5, it is shown that there was a small gap between fibre and matrix which means a poor adhesion or interfacial bonding for fibre with 20 vol%. The void and small gap formed was probably caused by incomplete wettability or bonding between matrix resin and fibre during the fabrication of composites. This was also reported by Arib et al. (2006) and Lee et al. (2005).

According to Baiardo et al. (2004) the mechanical properties of short fibre reinforced composites are expected to depend on (i) the intrinsic properties of both matrix and fibres, (ii) aspect ratio, content, length distribution and orientation of the fibres in the composite, and (iii) fibre–matrix adhesion that is responsible for the efficiency of load transfer in the composites.

FLEXURAL PROPERTIES OF OPF/EPOXY COMPOSITES

Flexural strength shows a decreasing trend as the volume fraction of fibre is increased (Figure 6). It can be found that 10 vol% of fibre has the highest average value of flexural strength which is 51 MPa, while fibre with 5 vol% has the lowest average value of flexural strength which is 40.9 MPa. Myrtha et al. (2008) found out that the flexural strength of empty fruit bunch/polyester composites for longer fibre is 36.8 MPa while for short fibre is 33.9 MPa both at 18 vol%. The result of the current study is slightly higher than the result obtained by Myrtha et al. (2008). It is also found that the composites have lower flexural

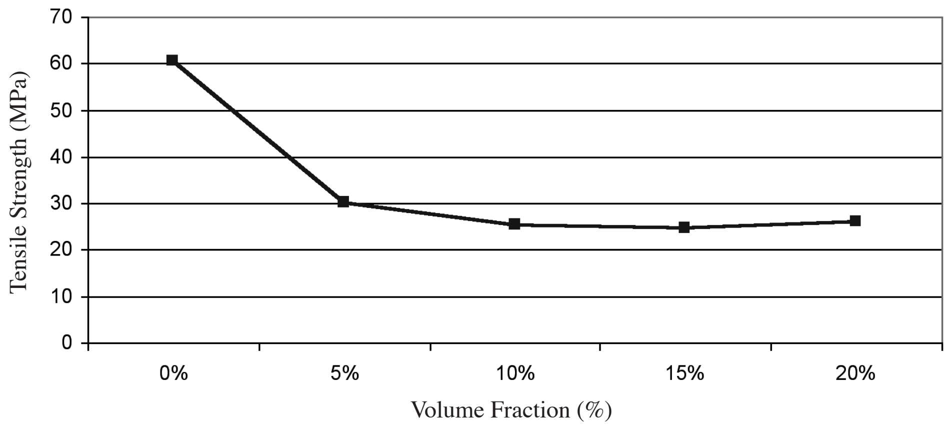

FIGURE 2. Tensile strength versus volume fraction of chopped random fibre composites

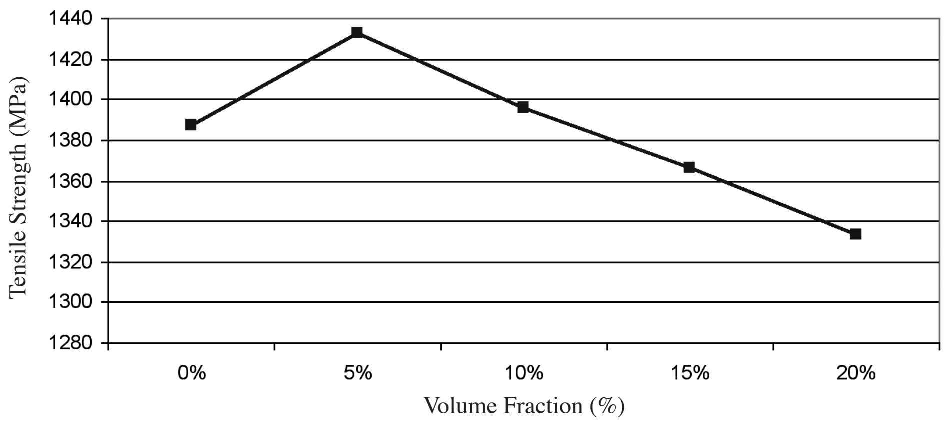

FIGURE 3. Young's modulus versus volume fraction of chopped random fibre composites

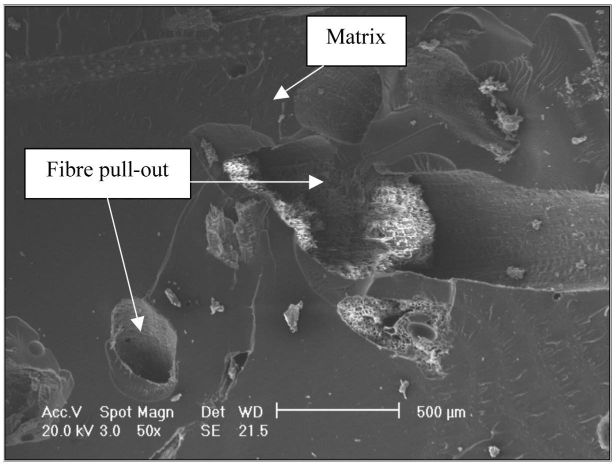

FIGURE 4. SEM showing the fibre pull-out from matrix

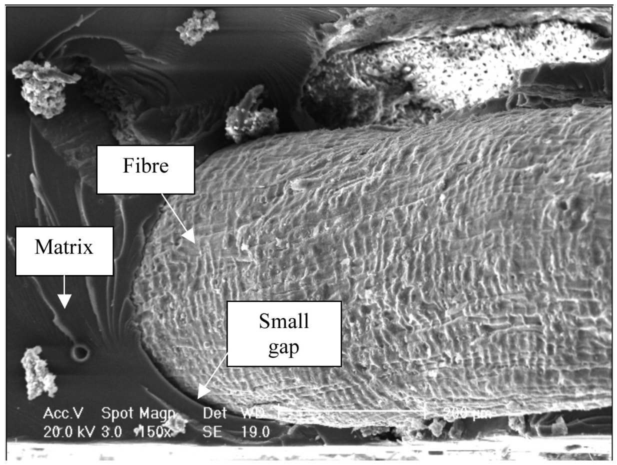

FIGURE 5. SEM showing a small gap between fibre and matrix

strength than the matrix alone (pure epoxy) and there is no significant effect of fibre content to the flexural strength of composites.

Figure 7 shows the flexural modulus of oil palm fibre reinforced epoxy composites. Flexural modulus tends to be decreased as the fibre content is increased. This trend is also similar to the flexural strength of oil palm fibre reinforced epoxy composites where by addition of fibre the value of flexural modulus is decreased. The reason is due to the alignment of fibres, interaction between fibre – matrix and bubbles arise during the fabrication of the composites plate.

It was also been reported by Azis and Ansell (2004) that the flexural strength value depended very much on

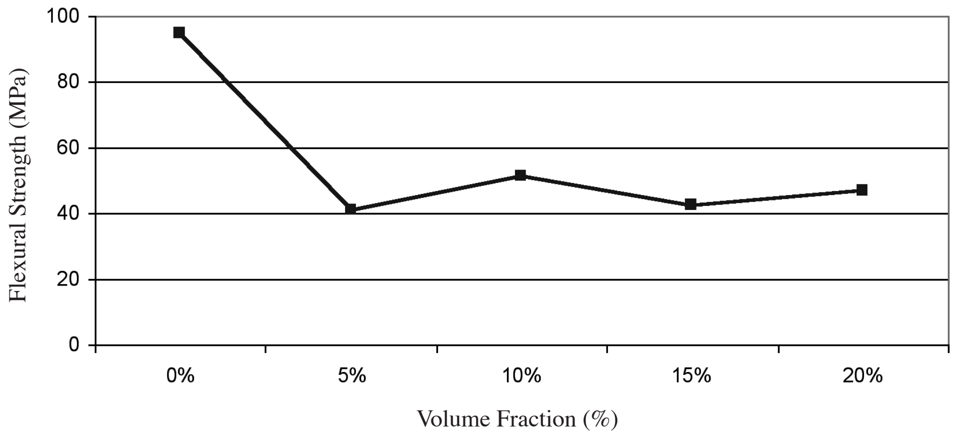

FIGURE 6. Flexural strength of oil palm fibre reinforced epoxy (OPF/epoxy) composites

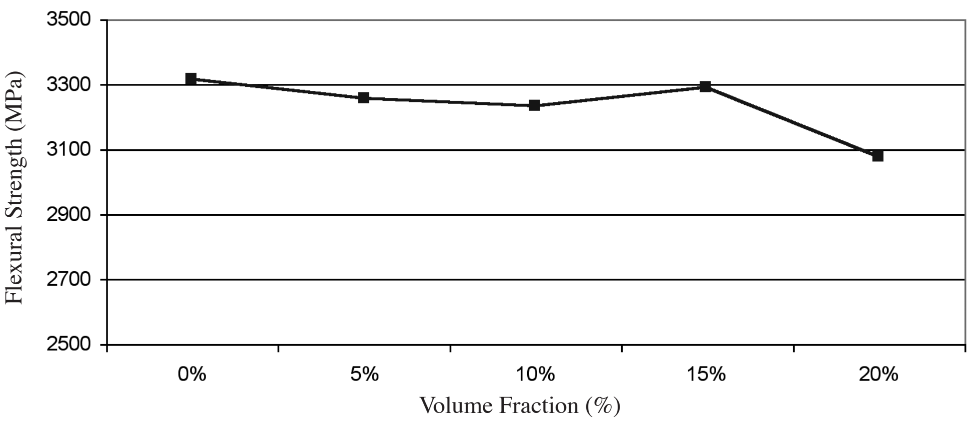

FIGURE 7. Flexural modulus of oil palm fibre reinforced epoxy (OPF/epoxy) composites

fibre alignment and the location of resin-rich areas. Li et al. (2000) stated that tensile properties of short-fibre-reinforced composites strongly depend on fibre length, fibre volume fraction, fibre dispersion, fibre orientation and fibre /matrix interfacial strength.

The results of the current study are compared with the results of the investigation such as Sastra et al. (2005) where the the Young's modulus of the chopped random *Arenga pinnata* fibre composite was much lower compared to the long random *Arenga pinnata* fibre composite. This is due to the random orientation of the fibres, which makes their mechanical properties inferior and many voids form in the specimen during the fabrication process.

Khalil et al. (2007) reported that the weak fibre/matrix bonding contributed to poor flexural properties. The efficiency of stress transferred between resin and fibre decreased from the weak interfacial regions. Factors that determine the quality of interfacial bonding include the nature of the fibre and binder as well as their compositions, the fibre aspect ratio, the types of mixing procedures, processing conditions employed and on the treatment of the polymer or fibre with various chemicals, coupling agents and compatibilizers.

Conclusions

In this paper, the tensile and flexural properties of short random oil palm fibre reinforced epoxy composites have been measured. Based on the results, it was found that tensile and flexural properties showed a decreasing trend as the fibre was increased. The optimum percentage of fibre in epoxy resin to obtain the highest tensile properties was found at 5 vol% but there was no significant effect of addition more than 5 vol% to the flexural properties of composites. It was also found that void, fibre length, dispersion of fibre and interfacial adhesion between fibre – matrix can affect the mechanical properties of the composites.

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