

FLEXURAL AND TENSILE PROPERTIES OF KENAF/GLASS FIBRES HYBRID COMPOSITES FILLED WITH CARBON NANOTUBES

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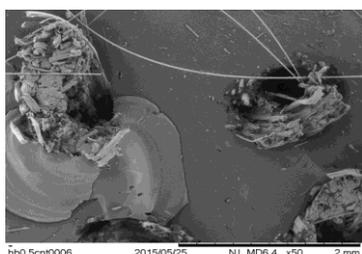
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Graphical abstract



Abstract

The usage of nanofillers reinforcement in polymer matrix has been recently explored for natural fibres composites to improve mechanical properties of polymers. In this study, 0.5 wt% , 0.75 wt% and 1.0 wt% of Carbon nanotubes (CNTs) were added into epoxy resin. The CNTs-modified epoxy resins were then used to produce kenaf/glass hybrid composites. The laminates were prepared using dry filament winding machine and hand lay up method. All samples were tested according to the ASTM Standards, i.e. D790 and D3039 for flexural properties and tensile properties, respectively. Experimental results obtained showed that the flexural strength decreases with increasing CNTs content, while the flexural modulus increases with increasing CNTs content. The tensile strength was found to decrease with the addition of 0.5 and 0.75 wt% CNTs but increase with the addition of 1.0 wt% CNTs. Hybridization with glass also showed an improvement in flexural and tensile properties of kenaf composite.

Keywords: Carbon Nanotubes (CNTs), kenaf fibres, glass fibres, hybrid composite, flexural properties, tensile properties

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1.0 INTRODUCTION

Natural fibres are increasingly being considered as a new renewable materials in substituting conventional and non-renewable materials (such as glass, carbon and aramid fibres). Natural fibres such as hemp, flax, jute, sisal, kenaf, banana and pineapple leaves offer several advantages including good mechanical properties (high specific strength and modulus), low density, good thermal behavior, wide availability, bio degradable and easy to fabricate[1-4]. Among natural fibres, kenaf is comparatively available and cheap to use in natural fibres reinforcing materials. Many reseachers revealed that kenaf fibres displayed better and superior properties for reinforcement in composites of different polymer matrix [2].

In the recent years, there has been an increasing interest in natural fibres reinforced with nano-modified polymer. Basically, the nanosize fillers such as nanoclay, nanosilica and carbon nanotubes

(CNTs) are added into polymer matrix to improve the stiffness, strength, toughness, dimensional stability and thermal properties [3-5]. However, the properties of these nanocomposite depends on various factors such as dispersion of nanofillers, the compatibility of the nanofillers with polymer matrix and the interfacial bonding of nanofillers with polymer matrix. Agglomerated particles and poor dispersion of nanofillers introduce premature failure of the nanocomposites system[4]. Weak bonding of nanofiller with polymer matrix will reduce the stress transfer and capability of nanocomposites.

CNTs as a nanofiller in polymer always attracted good attention in many field such as conducting plastics, aerospace structures, sports, biomaterials, automotive component, optical barrier,etc due to their excellent mechanical, thermal, chemical and electrical properties. Many researchers agreed that the addition of CNTs increased the properties of polymer nanocomposites when compared to neat polymer[5-7]. As reported by Balakrisnan, the

addition of 0.6wt% CNTs in epoxy resin enhanced Young's modulus about 23%[8]. Y. Lie et al, in their study found that the matrix modification by 0.5 wt% MWCNTs increased 25.4% interlaminar shear strength compared to the unmodified glass fibres/kenaf composites[9]. It is believed that the CNTs act as barriers for the stress lines therefore this reduces spots of high concentration stresses in the system under loading.

Hybrid composites with synthetic fibres such as glass fibres and carbon fibres always draw a good mechanical performance . A number of studies have found that the properties of hybrid composites depend on the fibres orientation, fibres content, fibres length, compatibility between resin and fibres, layering pattern of both fibres, extent of intermingling of fibres[10][11][12]. Previous study, the hybridization kenaf/carbon fibres reinforced polymer has shown an enhancement about 136 % in compressive strength and 160 % in tensile strength [11]. As reported by Norhashidah, the hybridization glass in yarn fibres kenaf increase the compressive and tensile properties of natural fibres apart from protecting the fibres from humidity [12].

In this paper, CNTs were used to modify the epoxy resin. The resin was then used in the fabrication of kenaf/glass fibres hybrid reinforced epoxy composites. The effect of CNTs content on mechanical properties of composite laminates was investigated. The CNTs were functioned as a modifier to improve the properties of epoxy matrix.

2.0 EXPERIMENTAL

2.1 Materials

The epoxy resin and hardener used for this study were supplied by Miracon (M) Sdn Bhd, Malaysia. A Flo Tub 9000 Series Multi-wall Carbon Nanotube (CNTs), used as a nanofiller, was supplied by CNano Technology (Beijing) Ltd, China. The Multi-wall Carbon Nanotubes (CNTs) were produced by a catalytic vapor deposition process with average diameter and length of 11nm and 10 μ m, respectively. The yarn kenaf fibres (as shown in figure 1) were supplied by Innovative Pultrusion Sdn. Bhd, Seremban, Malaysia. While , the woven glass fibres was supplied by Vistec Technology service, Puchong, Malaysia.

2.2 Fabrication of Kenaf/Glass/CNTs Hybrid Composites

Firstly, a series of CNTs (addition of 0.5wt%, 0.75wt% and 25wt%) has been mixed with epoxy resin using mechanical stirrer at 400 rpm for 1 hour. Then, the mixtures were degassed under high vacuum machine for 1 hour, followed by the hardener agent with ratio 100:30 (epoxy:hardener). Degassification

process was needed to remove entrapped air during the composite fabrication.

Kenaf/glass fibres hybrid composites were manufactured using a combination of dry filament winding and hand lay up methods. Kenaf fibres were wound on frame of 430 x 300 mm in one direction. The fibres glass were manually placed on top and bottom of wounded kenaf after applied the epoxy resin. The kenaf/glass fibres hybrid composites were vacuumed and left to cure at room temperature for 24 hours. Finally the samples were post cured at 60°C for 2 hours, followed by 60°C for 2 hours, 80°C for 2 hours, 100°C for 2 hours and 120°C for 2 hours.



Figure 1 Yarn Kenaf Fibres

2.3 Flexural Test and Tensile Test

The flexure strength and flexural modulus of kenaf/glass fibres hybrid reinforced epoxy composites were determined using a standard test for flexural properties of unreinforced and reinforced plastic as per ASTM D790-10. A span-to- depth ratio of samples was considered as 16:1. The tensile strength and tensile modulus of kenaf/glass fibres hybrid reinforced epoxy composites were determined according to ASTM D3039/D3039M-08. The rectangular samples with dimension of 250 x15 x 5 mm were used in this test. The INSTRON Universal Testing Machine was used to perform both flexural and tensile test with 100kN load cell and cross-head speed of 2 mm/min. At least 5 samples for each composites system were tested to determined the properties.

2.4 SEM Study

The tensile fracture surface of the Kenaf/glass fibres hybrid composites were examined using a portable HITACHI TM 3030 PLUS Scanning Electron Microscopy (SEM). The cross section of tensile test specimens were cut about 15mm height and sputter coated with platinum to make specimen surface conductive. The coating will reduce charging during the specimen viewing.

3.0 RESULTS AND DISCUSSION

3.1 Flexural Properties

Flexural strength and flexural modulus of kenaf/glass fibres hybrid reinforced epoxy composites with difference percentage of CNTs modified epoxy were compared and showed in figure 2 and table 1. It is interesting to note that the hybridization kenaf with glass results in a higher flexural strength when compare to the other kenaf composites system. The flexural strength decreases with increasing CNTs content. However, the flexural modulus increases with increasing CNTs content. It can be justify that the flexural strength and modulus for this kenaf/glass fibres hybrid reinforced epoxy composites are influenced by the addition and amount of CNTs. The lower flexural strength in higher CNTs content occurred due to poor dispersion of CNTs in epoxy resin. A high content of CNTs caused poorly dispersion CNTs in epoxy resin. This forms CNTs agglomerated regions due to the entanglements of the tubes. This may act as stress concentration points that lead to composites failure. Hence, this will lead the decrease of flexural strength. There are also reported by many researchers that the poor dispersion of nanofillers is the main cause that results in poor mechanical strength. The stiffness of the materials can be define by flexural modulus. In this case, the flexural modulus increase with increasing of CNTs content. It is believed that this is because of the high stiffness property of CNTs, thus this gives a good effect on the overall performance of the composites materials.

The details on tensile properties of of kenaf/glass fibres hybrid reinforced epoxy composites are summarized in table 1 and figure 3. The results showed that, the addition of 0.5 and 0.75 wt% CNTs reduce tensile strength of about 20% and 5%,

repectively. However, the tensile strength increases when 1.0 wt% CNTs was added into the composite system. The tensile strength which was obtained in this experimental work does not consistent to that reported by other researchers. Literature often shows an increasing trend of tensile strength with increasing CNTs content. Therefore, the microstructures of the samples were examined using a SEM, as shown in figure 4. SEM micrographs show the microstructure of 0.5wt% CNTs modified epoxy in kenaf composites compared to that of the pure system. In general, the micrographs show fracture mechanisms involved are micro cracking in epoxy matrix, fibres debonding and fibres pull out. It can be seen that some fibres from yarn kenaf fibres were broken and pulled-out for the CNTs modified kenaf composites system. This is may be due to a poor penetration of the epoxy resin into the kenaf fibres.

In contrast, Figures 2 and 3 show that the flexural modulus and tensile modulus increase with increasing CNTs content. As reported by a numbers researchers, the reinforcement efficiency of CNTs in a matrix depends on various factor such as dispersion of CNTs in matrix, volume fraction of fillers, type of matrix and filler bonding and aspect ratio as well as waviness of nanotubes[5][7]. On the other hand, it should be noted that natural fibres always drawn a lot of problems especially in developing high performance natural fibres reinforced polymer composites. Kenaf is one of the natural fibres type that used in this study due to their potential application for many industries. The ability of the kenaf to absorb moisture from the atmosphere leads to alteration in weights and dimension stability. This hydrophilic property of kenaf also give impact on weak interfacial bonding between fibres and matrix. This problem will lead to low strength and stiffness of the kenaf composites [1][13][14].

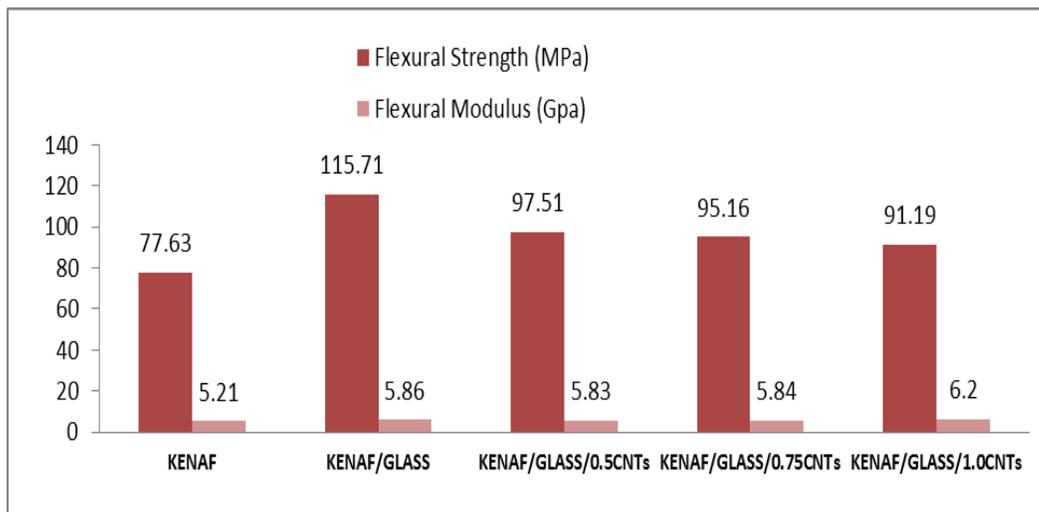


Figure 2 Flexural Modulus and flexural strength of kenaf/glass fibres hybrid reinforced epoxy composites enhanced with Carbon Nanotubes (CNTs)

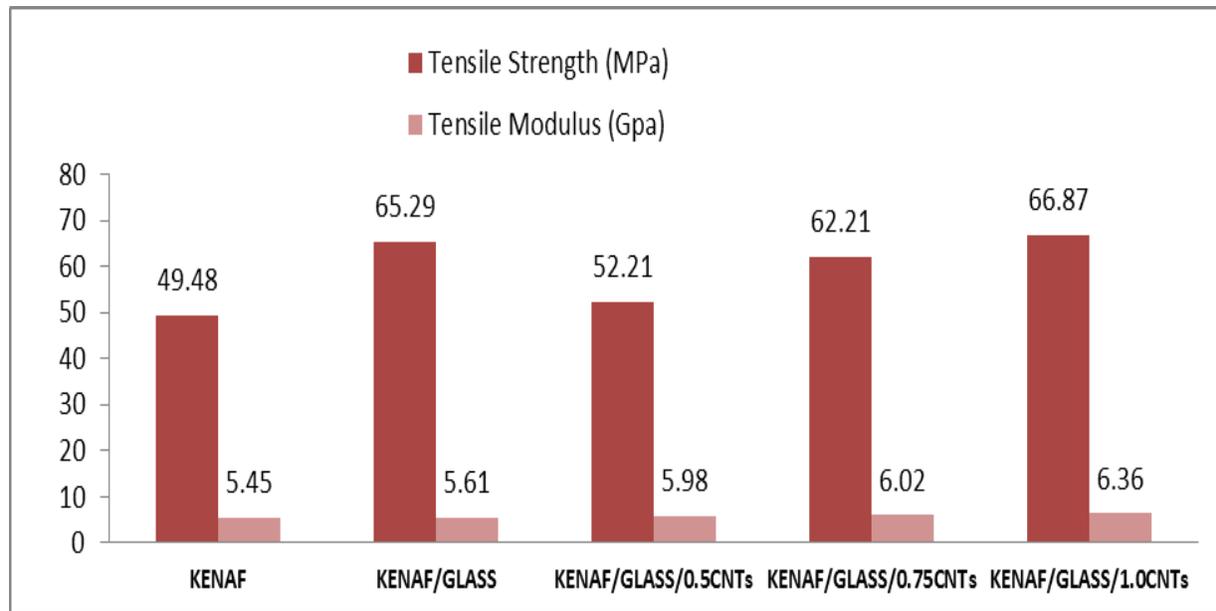


Figure 3 Tensile Modulus and Tensile strength of kenaf/glass fibres hybrid reinforced epoxy composites enhanced with Carbon Nanotubes (CNTs)

Table 1: Flexural and Tensile properties of kenaf/glass fibres hybrid reinforced epoxy composites enhanced with Carbon Nanotubes (CNTs)

PROPERTIES	KENAF	KENAF/ GLASS	KENAF/ GLASS/ 0.5CNTs	KENAF/ GLASS/ 0.75CNTs	KENAF/ GLASS/ 1.0CNTs
Flexural Modulus (GPa)	5.21±0.51	5.86±0.12	5.83±0.13	5.84±0.08	6.20±0.32
Flexural Strength (MPa)	77.63±15.00	115.71±6.04	97.51±2.66	95.16±8.72	91.19±7.97
Flexural extension at break (mm)	1.77±0.29	2.23±0.15	1.85±0.09	2.03±0.43	1.76±0.24
Flexural strain at Max Load (%)	2.09±0.305	2.78±0.23	2.27±0.01	2.35±0.41	2.28±0.38
Tensile Modulus (GPa)	5.45 ± 0.31	5.61± 0.37	5.98 ± 0.21	6.02 ± 0.60	6.36 ± 0.42
Tensile Strength (MPa)	49.48 ± 2.31	65.29 ± 9.16	52.21 ± 0.15	62.21± 0.76	66.87 ± 5.58
Tensile extension at break (mm)	3.22 ±0.038	4.04±0.15	3.46 ± 0.54	3.69± 0.075	4.20 ± 0.66
Tensile strain at Max Load (%)	1.37±0.015	1.67 ± 0.33	1.442± 0.22	1.49± 0.30	1.66 ± 0.26

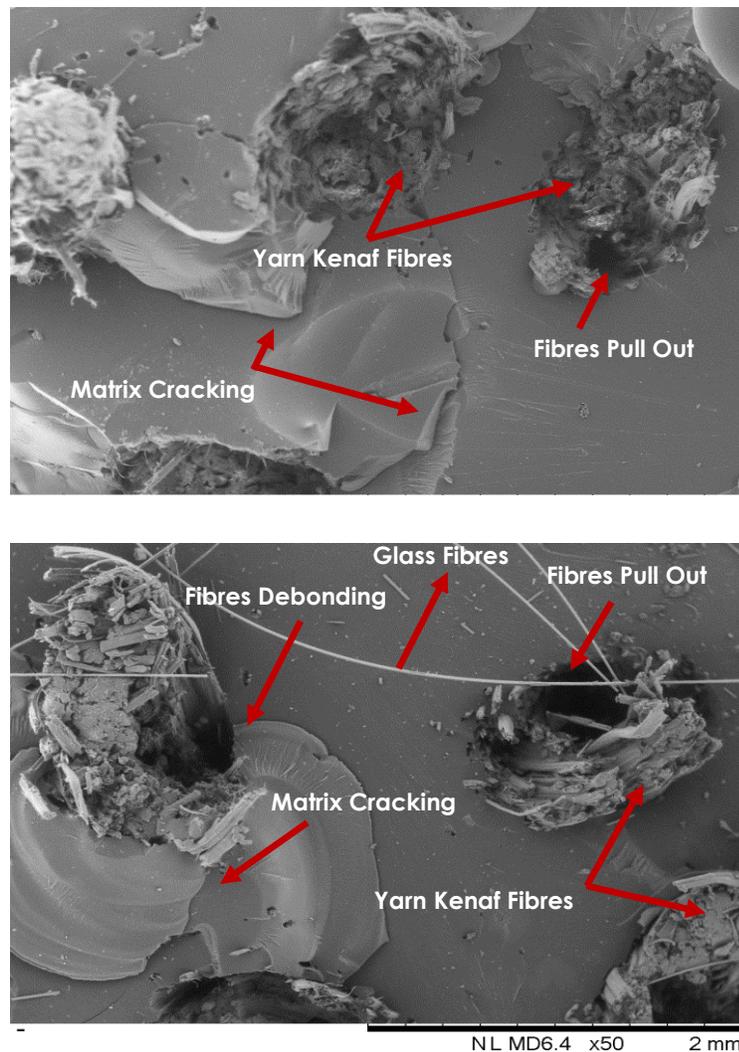


Figure 4 SEM images for (a) kenaf composite and (b) glass/kenaf fibres/0.5 wt% CNTs composite

4.0 CONCLUSION

The effect of CNTs on flexural and tensile properties of kenaf/glass fibres hybrid reinforced epoxy composites was studied. The flexural strength decreased with increasing in CNTs content. For tensile properties, tensile strength decreased for 0.5 wt and 0.75 wt% CNTs content but increased for 1.0 CNTs content. However, the flexural and tensile modulus increase with increasing in CNTs content. It was also observed that fibres pulling out during tensile test was the reason why the strength of the hybrid laminate decreased. The hybridization of glass and kenaf is a good combination to increase the mechanical properties of kenaf fibres. However, the effect of CNTs on overall properties of polymer matrix and composites, including physical, thermal, electrical, mechanical still needs to be further studied in order to improve the overall performance of kenaf/glass fibres hybrid reinforced epoxy.

tensile strength

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