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Characterization Of Rubber Toughened Epoxy Reinforced Hybrid Kenaf/Carbon Fiber Via Water Absorption And Thermal Degradation

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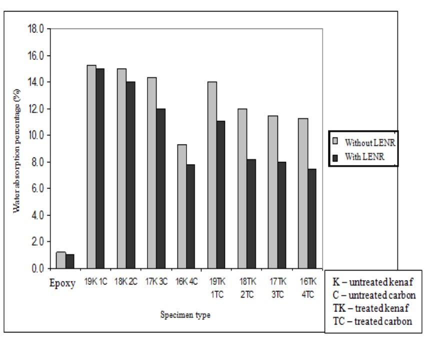
Graphical abstract



Abstract

Toughened epoxies reinforced by hybrid of kenaf/carbon fiber, untreated and treated, with the addition of liquid epoxidized natural rubber (LENR), were tested for their water absorption and thermal degradation. Water absorption testing was conducted based on ASTM D1037 to study the effects of kenaf fibre and carbon fibre on water uptake property. In the thermal analysis, the thermal degradation of the specimen was investigated towards heat. The test used a termogravimetric analysis machine, model Mettler Toledo-TGA, at temperature range of 50 ^{o}C to 350 ^{o}C with an increment of 10 ^{o}C/min where the results showed the decreasing of degradation temperature when the treated fiber was used. The results also showed that the percentage of water absorptions for composites with the addition of LENR were lower compared to those of composites without LENR.

Keywords: Thermal analysis, biocomposite, hybrid fibre, toughened

1.0 INTRODUCTION

A combination of two fibers in the composites will vary its mechanical properties and interfacial bonding with the matrix. Reducing the manufacturing cost and the usage of man-made fibres are the main objectives in developing such composites [1]. Hybrid composites with goodselection of fibrous reinforcements possibly will produce excellent properties and fulfill a current demand in polymer matrix composites. Kenaf (*Hibiscus cannabinus*, L. family *Malvaceae)* is an herbaceous annual plant that can be grown under a wide range of weather conditions that has advantages of economical and ecological properties which are in high interest to researchers as one of the reinforcement materials. Many researches using kenaf fibres as the reinforcement have been reported [2-5]. There is an increasing number of research towards hybridization of synthetic fiber and natural lignocellulose fiber [6-8].

Epoxy resins are characterized by the presence of a three membered ring known as the epoxy, epoxide, oxirane or ethoxyline group. Commercial epoxy resins contain aliphatic, cycloaliphatic or aromatic backbones. The most widely used one are epichlorohydrin and bisphenol-A derived resins. These epoxy resins are considered as one of the most important classes of thermosetting polymers and are extensively used for their many good properties which include high stiffness and strength, high creep resistance, good chemical resistance and adhesion to many substrates [9]. Epoxy was characterized by high chemical and corrosion resistance as well as good mechanical and thermal properties once cured. Many researches have been worked out to increase the toughness such as by using glass beads, alumina trihydrate and silica. The most successful works involving the addition of a suitable rubber such as liquid amine-terminated (ATBN)[9], carboxyl-terminated (CTBN)[10, 11], hydroxyl-terminated (HTBN)[12, 13], epoxy-terminated (ETBN) copolymers of butadiene and acrylonitrile [14], hydroxyl-terminated and epoxy-terminated polybutadiene to interpenetrating the polymer networks (IPN) structures [9]. Another method is by additionn of suitable rubbers that are copolymers with variable acrylonitrile contents to the uncured epoxy resins.

In this research, liquid epoxidized natural rubber (LENR) was introduced to the epoxy to increase its toughness. Hybrid kenaf/carbon fibers, with different ratios of kenaf/carbon %weight, were used to reinforce the epoxy resins (with and without addition of epoxidized natural rubber) as the matrices. The water absorption and thermal study of the rubber toughened epoxy reinforced hybrid kenaf/carbon fiber composites were investigated.

2.0 MATERIALS AND EXPERIMENTAL PROCEDURE

2.1 Materials

The epoxy (Morcote BJC 39) used in this study was supplied by Vistec Technology Sdn Bhd. Polyacrylonitrile (PAN) type CF was procured from Toray, Japan with 6 mm in length and 8 mm in diameter was treated using gamma radiation whilst the kenaf fibers were supplied by Symphony Advance Sdn Bhd, sieved with sizes range of 125–355 μm of a diameter in a form of loosely bound chop fibre were treated using NaOH solution. Polymer used was epoxidized natural rubber (ENR) purchased from Rubber Research Industries Malaysia (RRIM) whilst the liquid epoxidized natural rubber (LENR) was prepared by photochemical degradation technique in polymer laboratory, UKM according to the method described by Abdullah and Ahmad [15]. Epoxy resins were mixed with liquid epoxidized natural rubber at a concentration of 5.5 phr.

2.2 Composite Preparation.

The composites were fabricated in the form of plate using a stainless steel mould. The reinforcement of the kenaf fiber hybridized with carbon fiber in epoxy composites were evaluated at various fiber ratios, i.e. 19K/1C, 18K/2C, 17K/3C and 16K/4C with overall fiber contents of 20 wt% fiber loading. Both fibers were mixed with the matrices using mechanical stirrer for an hour. Later, stoichiometric amount of hardener was added to the mixture. Then, the mixture was poured into the mould. The mould was then placed between the heated platens of 8 MPa at 100°C (hot pressed) for 40 minutes. Then, the plates were cut into dimensions using diamond blade cutter according to ASTM required.

2.3 Water Absorption Test

The water absorption test was conducted according to ASTM D1037 to observe the effects of kenaf and carbon fiber towards water absorption percentage level. Specimen of 20 x 20 mm in size was soaked in distilled water for 120 days at room temperature. Water absorption percentage at specific time (M_t) was calculated as,

$$M_t = \frac{W_i - W_t}{W_t} \times 100$$

where W_i and W_t is the dry weight of specimen before and after soaking at it specific time.

2.4 Thermogravimetry Analysis (TGA)

Thermal degradation studies of the composite were performed using Metler Toledo STGA851 thermogravimetric analyzer from room temperature to 650°C with a heating rate of 10°C/min in nitrogen gas flow.

3.0 RESULTS AND DISCUSSION

3.1 Flexural Test

Figure 1 shows the result of water absorption for hybrid kenaf/carbon fiber reinforced epoxy composites with and without LENR addition. From the Figure 1, it was observed that increasing in kenaf fibre for hybrid composites tends to increase the water absorption percentages. This is due to the increasing of hydroxyl group in the composites due to the content of kenaf fiber as

reported by Ismail, et al. [16]. Increasing in the carbon fiber ratios showed the improved water resistance of the composites. This is consistent with the carbon fiber characteristic which has lower hydroxyl group compared to kenaf fiber, therefore better moisture resistance. Similar result were reported by John and Naidu [17] in the analysis of the sisal/glass fiber hybrid composite.

Figure 2 shows the result of thermogravimetric analysis of untreated and treated fiber hybrid composites without and with the addition of LENR whilst the decomposition percentages of the composites are in the range of 83 to 87% as shown in Table 1.

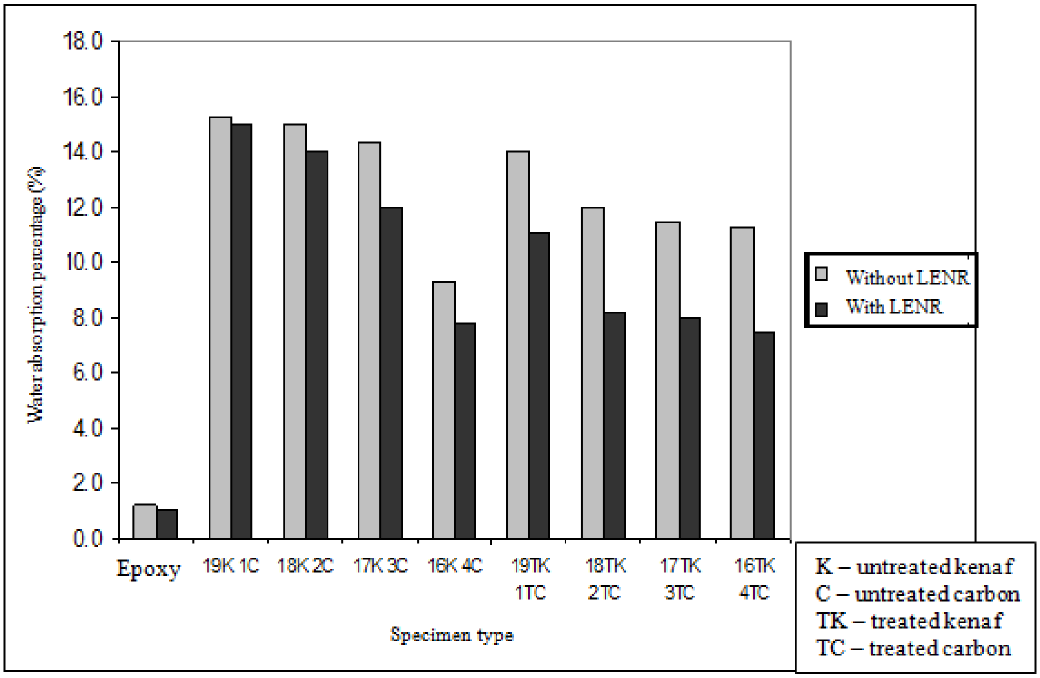


Figure 1 Water absorption percentage of epoxy reinforced hybrid kenaf/carbon fiber composite with and without LENR after 120 days.

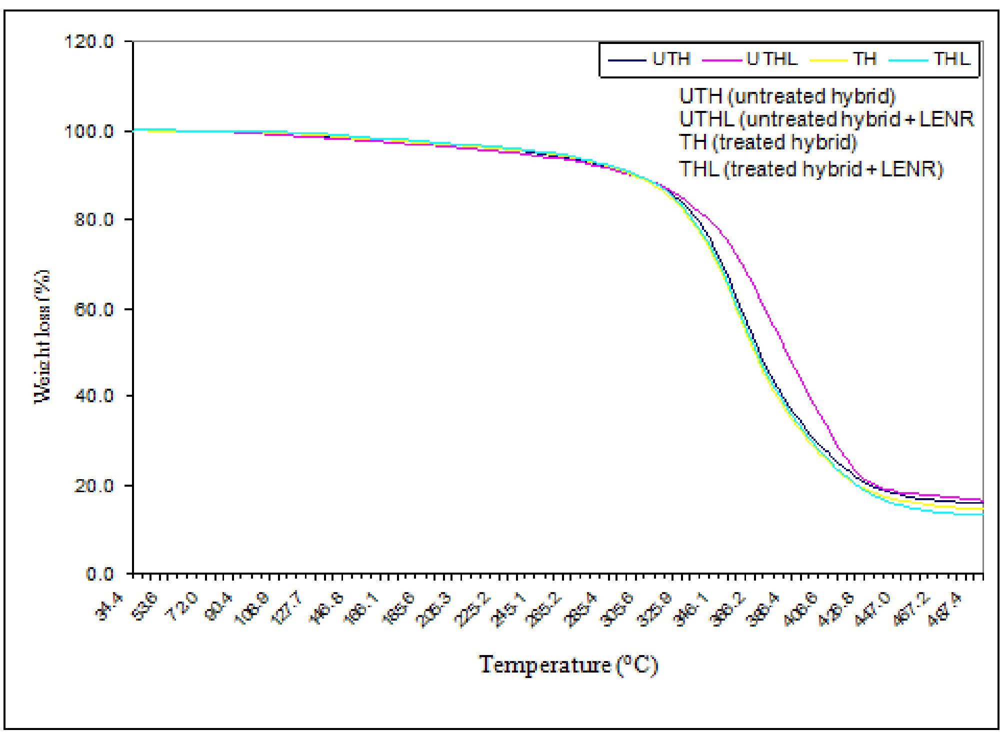


Figure 2 Comparison of TGA curve of epoxy reinforced hybrid kenaf/carbon fibre composite

On set temperature at 10% weight loss and decomposition percentage was taken from TGA analysis. It can be seen from the Table 1 that treated hybrid fiber resulted in decreasing in degradation temperature.

Several factors could affect this condition such as high cross linking, fiber orientations, fiber length and fiber wetted condition by matrix which are reported by Noor Najmi, et al. [18]. Interfacial bonding between the fiber and matrix is more dominant compared to other factors [19].

Table 1 Temperature at 10% weight loss and decomposition percentage of reinforced hybrid kenaf/carbon fiber composites

Specimen	Temperature at 10% weight loss (°C)	Decomposition percentage (%)
UTH	300.5	84.2
UTHL	295.4	83.2
TH	296.2	85.5
THL	302.5	86.7

4.0 CONCLUSION

From this study it can be concluded that:-

1) Hybrid kenaf/carbon fiber reinforced epoxy composite with the LENR has a lower water absorption compared to composites without the addition of LENR. Increasing carbon fiber loadings decreased the water absorption percentage.
2) Thermogravimetric analysis shows that decomposition percentage is between 83 to 87%. Treated fibers resulted in decreasing in degradation temperature compared to the untreated one.

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