Jurnal
Teknologi

Full Paper

Mechanical Performance Of Modified Epoxy Reinforced Hybrid Natural Fiber Composite

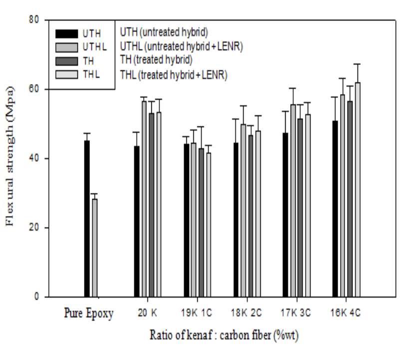
Mimi Azlina Abu Bakar[a*], Sahrim Ahmad[b], Salmiah Kasolang[a], Mohamad Ali Ahmad[c] , Nik Roselina Nik Roseley[a], Siti Norazlini[a], Wahyu Kuntjoro[a]

[a]Faculty of Mechanical, Universiti Teknologi Mara, 40450 Shah Alam, Selangor, Malaysia
[b]Polymer Research Centre (PORCE), Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[c]Mechanical Engineering Section, Faculty of Engineering, Universiti Kuala Lumpur International College, 43600 Bangi, Selangor, Malaysia

Article history
Received
13 February 2015
Received in revised form
11 May 2015
Accepted
31 May 2015

*Corresponding author
mimi_azlina@salam.uitm.edu.my

Graphical abstract



Abstract

Kenaf fiber that is known as Hibiscus cannabinus, L. family Malvaceae is an herbaceous plant that can be grown under a wide range of weather conditions. The usage of kenaf fibers as a reinforcement material in the polymeric matrix has been widely investigated. In this research, liquid epoxidized natural rubber (LENR) was introduced to the epoxy to increase its toughness. Hybrid kenaf/carbon fibers, with different kenaf/carbon ratio weight, were used to reinforce the epoxy resins (with and without addition of epoxidized natural rubber) as the matrices. The flexural strength, flexural modulus and fracture toughness of the rubber toughened epoxy reinforced hybrid kenaf/carbon fiber composites were investigated. The results showed that the addition of liquid epoxidized natural rubber (LENR) had improved the flexural strength, flexural modulus and fracture toughness by 9.6%, 13.7%, and less 2% respectively at the ratio of 16:4 wt% fibre loading.

Keywords: Biocomposite, kenaf fibre, natural rubber, toughened hybrid

1.0 INTRODUCTION

Currently, using natural fibers as a reinforcement for polymer composites is well known for major studies due to its properties such as lightweight, renewable, low density, high specific strength, non-abrasive, low combustibility, non-toxic, low cost and biodegradable [1-3]. The natural fiber used in this study was kenaf because of being low cost and light. Kenaf is obtained from stems of plants genus Hibiscus family of Malvaceae and the species of H.cannibinus and one of the natural fibers that highly researched as reinforcement materials in composite. Previous studies on kenaf composites were carried out to enhance the composite properties as reported in [4-7]. There is a number of recent studies on hybridization of synthetic fiber and natural lignocellulose fiber [8-10]. A combination of the two types of fibers in composites tends to vary their mechanical properties and the interfacial bonding within the matrix. Reduction on the manufacturing cost and the usage of man-made fiber have been the main objectives in developing such composites [11]. Hybrid reinforcement with good selection of fibers is likely to produce excellent properties and fulfill the current demand for polymer matrix composites.

In this research, liquid epoxidized natural rubber (LENR) was introduced to increase the toughness of the epoxy composites. Hybrid kenaf/carbon fibers, with different kenaf/carbon weight ratio, were used to reinforce the epoxy resins (with and without addition of epoxidized natural rubber). The flexural strength, flexural modulus and fracture toughness of the rubber toughened epoxy reinforced hybrid kenaf/carbon fiber composites were investigated.

2.0 MATERIALS DAN EXPERIMENTAL PROCEDURE

2.1 Materials

The epoxy (Morcote BJC 39) used in this study was supplied by Vistec Technology whilst Polyacrylonitrile (PAN) type carbon fibre (CF) was procured from Toray, Japan with 6mm in length and 8 mm in diameter. Kenaf fibers were supplied by Symphony Advance, sieved with sizes range of 125–355 µm of diameter in a form of loosely bound chop fibre and the aspect ratio is 7.5. This carbon fiber was treated using gamma radiation whilst the kenaf fiber was treated using 5% NaOH solution. Polymer used was epoxidized natural rubber (ENR) purchased from Rubber Research Industries Malaysia (RRIM). Liquid epoxidized natural rubber (LENR) was prepared by photochemical degradation technique according to the method described by Abdullah and Ahmad [12]. 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 measuring 165 × 165 × 3 mm. The reinforcement of the kenaf fiber hybridized with carbon fiber in epoxy composites were evaluated at various fiber loadings with overall fiber contents of 20 wt%. Hybrid composites with different ratios, i.e. 0.9:0.1, 0.8:0.2, 0.7:0.3 and 0.6:0.4 of kenaf/carbon fiber were prepared. Fibers and the epoxy were mixed using mechanical stirrer for an hour and later a specific hardener was added. The mixture was poured into the mould and then placed between heated platens with a pressure of 8 MPa at 100°C for 40 minutes. The plates were cut using diamond blade cutter into required dimensions depending on the types of testing.

2.3 Flexural Test

The flexural strength and modulus were determined according to ASTM D790-96. A gauge length of 100 mm was deployed with a cross-head speed of 5 mm/min using the Shimadzu Universal Testing Machine (model: Autograph AG-X 50kN).

2.4 Fracture Toughness Test

Fracture toughness was measured under three-point bending approach using the Shimadzu Autograph AG-X 50-kN Universal Testing Machine according to the ASTM D5045 standard. A gage length of 80mm was deployed with a crosshead speed of 2 mm/min.

3.0 RESULTS AND DISCUSSION

In Figure 1, it was observed that increasing carbon fibre composition tends to increase the flexural strength of hybrid composite. This is similar to what was observed by Rozman, et al. [9] where it was reported that flexural strength decreases as natural fiber composition increase. Treated hybrid (TH) composites tend to have a higher flexural strength compared to untreated hybrid (UTH) composite which produced 15.2% improvement. Kenaf fiber treated by alkaline and carbon fiber treated by gamma ray contributed to the strong interfacial bonding between fiber and matrices epoxy [14]. The higher value of flexural strength was given by treated hybrid epoxidized with natural rubber (THL) by the composition of 16 wt% kenaf and 4 wt% carbon fiber. Based on Fig. 1, adding LENR tends to increase the flexural strength from 56.4 MPa (UTHL) to 61.8 MPa (THL) for the ratio of 16:4 wt% kenaf/carbon fiber composite.

Figure 2 shows the result of flexural modulus of epoxy reinforced hybrid kenaf/carbon fiber composites. It was observed that flexural modulus has a similar trend as the flexural strength. Generally, adding carbon fiber to composites tends to increase the composite flexural modulus in all cases for both treated hybrid (TH) and untreated hybrid (UTH) by as much as 12% improvement for 16 wt% kenaf fiber and 4 wt% carbon fiber.

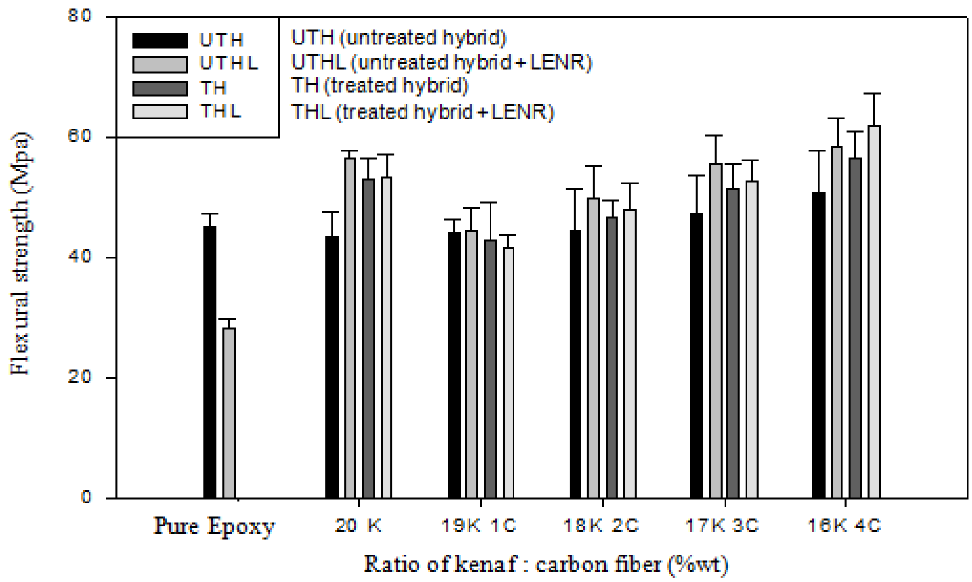


Figure 1 Flexural strength of epoxy reinforced hybrid kenaf/carbon fibre composite

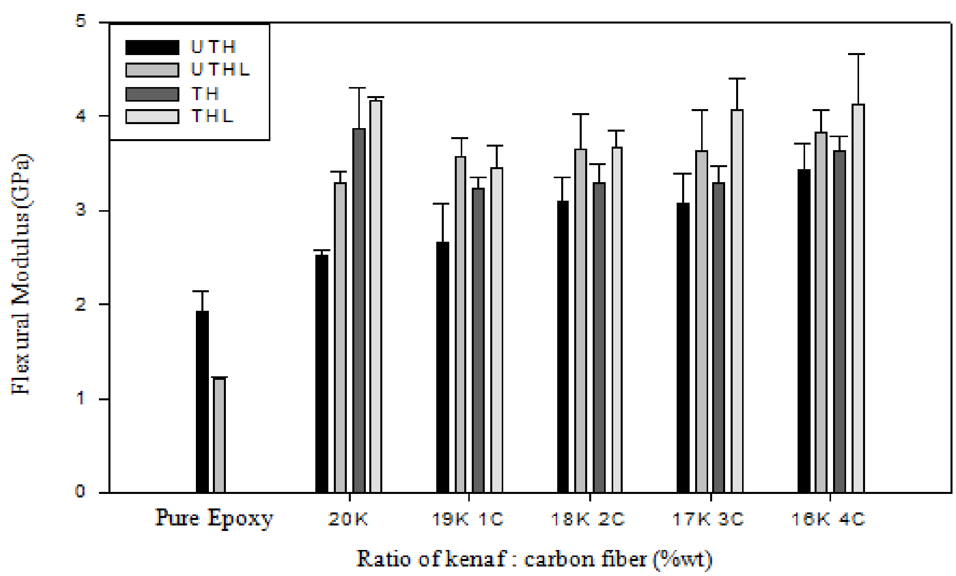


Figure 2 Flexural modulus of epoxy reinforced hybrid kenaf/carbon fiber composite

Adding LENR to the composite has increased the flexural modulus for both THL and UTHL by as much as 13.7% for 16 wt% kenaf fiber and 4 wt% carbon fiber. This was expected due to the contribution of rough fiber surface resulting from the treatment process. The rubber particle functioned as an absorbent to absorb stress concentration in the matrices.

Figure 3 shows the fracture toughness of epoxy reinforced hybrid kenaf/carbon fiber composite. From the figure, it was observed that increasing the carbon fibre composition tends to increase fracture toughness for all types of composite system except for TH composite. Haasen, et al. [13] reported that rough carbon fiber surface from treatment process caused the fiber to become brittle and fragile. Even though the fiber treatment can increase the shear stress between laminar and its flexural properties, treated carbon fibre can also cause losses in fracture toughness or notch tensile strength.

In Figure 3, at the composition of 4 wt% carbon fiber, THL composite has the highest fracture toughness value of 2.73 MPa.m$^{1/2}$ compared to TH composite with fracture toughness of 2.68 MPa.m$^{1/2}$. UTHL and UTH composites have fracture toughness of 2.70 and

2.67 MPa/m$^{1/2}$ respectively. Increment of fracture toughness for all composite was not highly increased compared to the increment observed in flexural strength and flexural modulus.

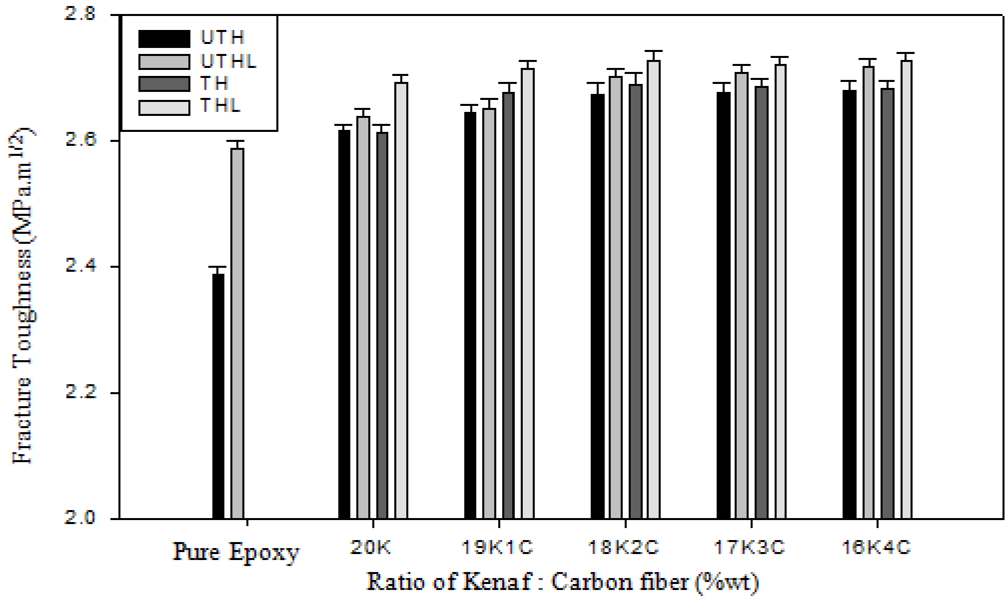


Figure 3 Fracture taughness of epoxy reinforced hybrid kenaf/carbon fiber composite

Based on Figure 3, it was observed that adding LENR to THL composite tend to increase the fracture toughness. The uniform distribution of rubber particles in matrices is believed in reducing stress concentration and crack distributions.

4.0 CONCLUSION

From this study it can be concluded that:-

1) Using treated fiber and adding LENR tend to increase the mechanical properties of the composite especially the flexural strength (10%) and flexural modulus (12 – 13.7%) at the ratio of 16 : 4 wt% kenaf : carbon fiber.
2) Fracture toughness of epoxy reinforced hybrid kenaf/carbon composite was less affected by the condition of treated and untreated materials. However, adding LENR has improved the fracture toughness by reducing stress concentration and crack distributions within the composite.

Acknowledgement

The authors would like to express their gratitude to the Ministry of Education of Malaysia (MOE), Fakulti Sains Teknologi (FST) UKM and Research Management Institute (RMI) UiTM Shah Alam for giving financial support through [600-RMI/ST/DANA 5/3/Dst (471/2011)]. The authors are also in debt to the Faculty of Mechanical Engineering (FKM) UiTM Shah Alam for facilitating this project.

References

[1] Chin, C. W. and Yousif, B. F. 2009. Potential of kenaf fibres as reinforcement for tribological applications. *Wear*. 267: 1550-1557.

[2] Ray, D., Sarkar, B. K, Rana, A. and Bose, N. R. 2001. Effect of alkali treated jute fibres on composite properties. *Bulletin Of Materials Science*. 24: 129-135.

[3] Ray, D., Sarkar, B. K. Rana, A. and Bose, N. R. 2001. The mechanical properties of vinylester resin matrix composites reinforced with alkali-treated jute fibres. *Composites Part A: Applied Science And Manufacturing*. 32: 119-127.

[4] Kasolang, S., Ahmad, M. A., Ghazali, F. A. and Azmi, A. M. 2011. Preliminary study of dry sliding wear in Kenaf Epoxy and Carbon Epoxy composites. *Applied Mechanics and Materials*. 52: 464-469.

[5] Kasolang, S., Ahmad, M. A., Bakar, M. A. A. and Hamid, A. H. A. 2012. Specific wear rate of kenaf epoxy composite and oil palm empty fruit bunch (OPEFB) epoxy composite in dry sliding. *Jurnal Teknologi (Sciences and Engineering)*. 58: 85-88.

[6] Bakar, M. A. A., Ahmad, S., Kuntjoro, W. and Kasolang, S. 2013. Effect of Carbon Fibre Ratio to the Impact Properties of Hybrid Kenaf/Carbon Fibre Reinforced Epoxy Composites. *Applied Mechanics and Materials.* 393: 136-139.

[7] Bakar, A., Ahmad, S. and Kuntjoro, W. 2012. Effect of Epoxidized Natural Rubber on Mechanical Properties

Epoxy Reinforced Kenaf Fibre Composites. *Pertanika Journal of Science & Technology*. 20.

[8] Mishra, S., Mohanty, A., Drzal, L., Misra, M., Parija, S., Nayak, S. and Tripathy, S. 2003. Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. *Composites Science and Technology*. 63: 1377-1385.

[9] Rozman, H., Tay, G., Kumar, R., Abusamah, A., Ismail, H. and Mohd Ishak, Z. 2001. Polypropylene–oil palm empty fruit bunch–glass fibre hybrid composites: a preliminary study on the flexural and tensile properties. *European Polymer Journal*. 37: 1283-1291.

[10] Sreekala, M., George, J., Kumaran, M. and Thomas, S. 2002. The mechanical performance of hybrid phenol-formaldehyde-based composites reinforced with glass and oil palm fibres. *Composites Science and Technology*. 62: 339-353.

[11] Bunsell, A. and Harris, B. 1974. Hybrid carbon and glass fibre composites. *Composites*. 5: 157-164.

[12] Abdullah I. and Ahmad, S. 1992. Liquid natural rubber as a compatibiliser in the blending of natural rubber with polypropylene. *In Materials Forum.* 353-357.

[13] Haasen, P., Kramer, E. J., Meijer, H. E. and Cahn, R. W. 1997. *Materials Science And Technology: A Comprehensive Treatment*. 18: VCH.

[14] Abu Bakar, M.A., Ahmad, S. and Kuntjoro, W. 2010. The mechanical properties of treated and untreated kenaf fibre reinforced epoxy composite. *in Journal of Biobased Materials and Bioenergy.* 49(2): 159-163