Journal of Mechanical Engineering and Sciences (JMES)
ISSN (Print): 2289-4659; e-ISSN: 2231-8380; Volume 5, pp. 631-638, December 2013

DOI: http://dx.doi.org/10.15282/jmes.5.2013.9.0060

MECHANICAL PROPERTIES OF ACTIVATED CARBON (Abdullah, Al-Asady, Ariffin, & Rahman) COIR FIBERS REINFORCED WITH EPOXY RESIN

Z. Salleh[1*], M.Y.M.Yusop[1] and M.S.Rosdi[1]

[1]Universiti Kuala Lumpur, Applied Science & Advanced Technology Section,
Malaysian Institute of Marine Engineering Technology, Dataran Industri Teknologi
Kejuruteraan Marin, Bandar Teknologi Maritim, Jalan Pantai Remis
32200 Lumut Perak, Malaysia.
[*]Email: zulzamri@mimet.unikl.edu.my
Phone: +6056909000; Fax: +6056909091

ABSTRACT

This research is to develop a carbon composite prepared from carbon coir fibers that is reinforced with epoxy resin. Carbon coir fibers were taken from three types of coir fiber specifically designated as CKCF, CYCF and CRCF. The samples were prepared using epoxy resin reinforced with carbon at different weight percentages for three types of coir fiber starting with 0wt.%, 2wt.%, 4wt.%, 6wt.%, 8wt.% and 10wt.%. The mechanical properties such as tensile stress and impact strength were used to characterize all the samples. The morphological study of reinforced samples was also conducted in this research using a SEM machine. The characteristics of all the composite materials were also investigated and discussed. It was determined that the CKCF sample exhibited better mechanical properties than the other coir fiber composites, having a higher average tensile stress value at 11.80MPa and higher impact strength values ranging from 268J to 276J at different carbon content. CKCF with 10wt% AC content had a tremendous impact strength compared with CYCF and CRCF.

Keywords: coconut; epoxy resin; reinforced; tensile.

INTRODUCTION

Coconut (Cocos nucifera) is a member of the palm family. Coconut plantations have spread all over the world typically in tropical and sub-tropical regions, where it is an important commodity in the economy of many countries. In 2011, nearly 100,000 hectares of land were utilized for coconut plantation, yielding over 577,000 MT of coconuts annually (UNCTAD, 2012) thus putting Malaysia as the 10th largest coconut-producing country in the world (DOA, 2012). The coconut palm is used for decoration as well as for its many culinary and non-culinary uses; virtually every part of the coconut palm has some human use. Fibers extracted from the husk of the nut, known as coir fiber, are now being commercially used, blended with natural rubber latex in the production of seat cushion parts in automobiles (Bachtiar, Sapuan, & Hamdan, 2010; Jeffrey, arlochan, & Rahman, 2011; Ravi Sankar, Srikant, Vamsi Krishna, Bhujanga Rao, & Bangaru Babu, 2013; Schuh & Gayer, 1997). These fibers are extracted from the external layer of the exocarp and from the endocarp of the fruit. The coconut palm can, in fact, be regarded as an integral fiber producer because fibers can be extracted from many parts of the palm, such as from the leaf sheath, the bark of the petiole or from the midribs of leaves (Satyanarayana et al., 1982; Venkataswamy, Pillai, Prasad, & Satyanarayana, 1987).

Many works have been devoted to the use of other natural fillers in composites in the recent past as potential candidates for the development of new composites because of their high strength and modulus properties (Monteiro, Lopes, Ferreira, & Nascimento, 2009). Composites of high-strength coconut filler can be used in a broad range of applications such as building materials, marine cordage, fishnets, furniture, and other household appliances (Mohanty, Misra, & Hinrichsen, 2000). Furthermore, due to environmental factors, natural carbon such as carbon from coconut has many advantages over traditional polymer fillers. These include low cost, low energy consumption, non-abrasive nature, safety in handling, low density, potentially higher volume fraction, superior specific properties, etc. Activated carbon (AC) made from natural sources has been proved to be the most economical adsorbent for waste water treatment (Eichhorn et al., 2001). AC is a porous carbonaceous material which has a high adsorption capacity and can be used as an adsorbent in industries for the purpose of liquid and gas purification and also as a catalyst and catalyst support. Industries that employ AC in their treatment processes are the food and beverages industries, pharmaceuticals, automobiles and mining. In this work, AC was produced from three types of coir fiber, namely Carbon Komeng Coir Fiber (CKCF), Carbon Young Coir Fiber (CYCF) and Carbon Ripe Coir Fiber (CRCF). The SEM image for CKCF composite, and the tensile strength and impact strength at different carbon content for all coir fibers were revealed. Composites were fabricated using carbon coir fiber as the reinforcement and epoxy resin as the matrix.

EXPERIMENTAL SETUP

Design of Experiment

All the coir fibers were weighed using a digital weighing machine, then cleaned with fresh water and dried at room temperature. After that, all the coir fibers were heated in an oven at a temperature of approximately 80^{o}C for 5 minutes until they became coal or powdered ash. The resin used was epoxy resin 3554A with a density of 1.15g/cm^3. The open mold type was used with a rectangular shape in accordance with the ASTM D256 standard for Izod impact tests, and dumbbell-shaped samples were produced in accordance with the ASTM D2099 standard for creep tests. Each mold can produce a maximum of 15 specimens at any one time. Epoxy and hardener were mixed in a container and stirred well for 5–7 minutes. Before the mixture was placed inside the silicon rubber mold (SRM) shown in Figure 1, the mold was initially polished with a release agent or wax to prevent the mixture from sticking onto the mold upon removal. Finally, the mixtures of carbon coir fibers (CKCF, CYCF and CRCF) and epoxy resins were poured into the mold and left at room temperature for 24 hours until the mixture hardened.

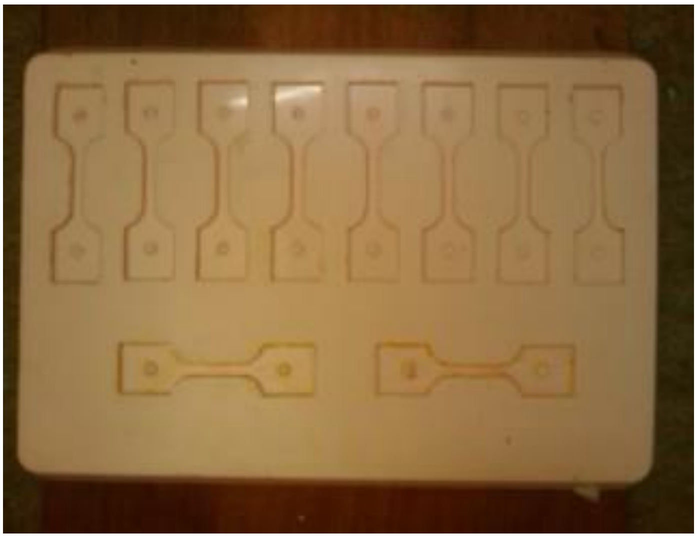


Figure 1. Silicon rubber mold (SRM)

Experimental Procedure

Tensile strength indicates the ability of a composite material to withstand forces that pull it apart, as well as the capability of the material to stretch prior to failure. The Izod impact strength is the ability of the composite material to withstand bending forces applied perpendicular to its longitudinal axis. The test was carried out with impact energy of 5J for samples having a span length of 60 mm at an angle of 30^o. Figure 2 shows the Universal Tensile Machine (UTM) and Izod impact test machine. The average value of un-notched Izod impact energy was obtained from each of the specimens. The SM106 creep measurement apparatus is shown in Figure 3, with the location of the specimen in the sample holder. The surface of the specimens was examined directly by SEM (scanning electron microscope). The eroded samples were mounted on stubs with silver paste. To enhance the conductivity of the eroded samples, a thin film of gold was vacuum-evaporated onto the samples before photomicrographs were taken.

(a) (b)

Figure 2. (a) Universal Tensile Machine (UTM); (b) Izod impact testing machine.

Figure 3. Specimen in sample holder of creep tester.

RESULTS AND DISCUSSION

Figure 3 shows the tensile stress for all the CKCF, CYCF and CRCF samples with different carbon content (wt.%). It is evident that the tensile stress trend for the CKCF composite increased slightly from 2wt.% to 4wt.%, while the maximum tensile stress is 13.42MPa. However, the tensile stress decreases for the 4wt.% to 8wt.% samples, though this increases again for the 10wt.% samples. Compared to the CYCF and CRCF composites, the tensile stress decreases dramatically, even though the initial tensile stress value for the CYCF is higher for the 2wt.% samples. Higher carbon contents might have strengthened the CKCF samples more effectively than the CYCF and CRCF samples.

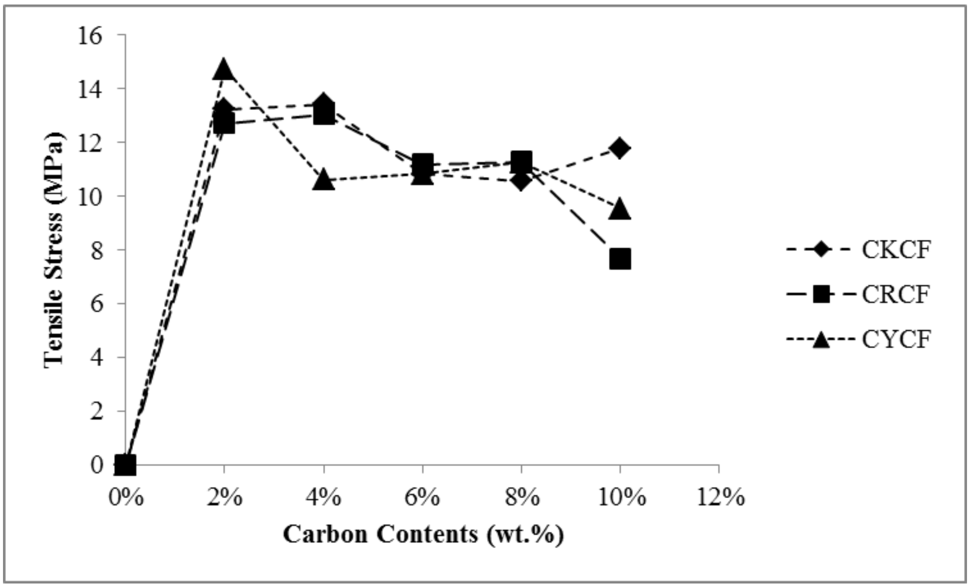


Figure 3. Tensile stress for CKCF, CYCF and CRCF composites.

The mechanical properties of the carbon coir composites depend on several factors such as the stress–strain behaviors of the carbon and matrix phases, the phase volume fractions, the carbon concentration, the distribution and orientation of the carbon or fillers relative to one another (Sapuan, Harimiand, & Maleque, 2003). The maximum tensile strength for 2wt.% of filler composite was higher (14.73MPa) for CYCF than for the other two combinations. CKCF composite shows a slightly higher tensile stress at 4wt.% filler content (13.42MPa) compared to its 2wt.% variant. The trend for carbon concentration from 2wt.% to 8wt.% shows that both CKCF and CRCF exhibited similar strength, but beyond that the CKCF samples exhibited a higher tensile stress value, averaging 11.80MPa. At a lower concentration of filler material, the CYCF and CRCF specimens demonstrated a slightly linear behavior prior to a sharp failure or fracture. It can be deduced that the specimen deformed plastically immediately after elastic deformation. Figure 4 shows the Izod impact test result for different wt.% for all samples. The impact performance of fiber-reinforced composites depends on many factors including the nature of the constituent, carbon/matrix interface, the construction and geometry of the composite and test conditions. The nature of the interface region is of extreme importance and is directly related to the toughness of the composite (Bledzki, Mamun, & Volk, 2010). The impact strength of a composite is influenced by many factors, including the toughness properties of the reinforcement, the nature of the interfacial region and frictional work. It was observed that the Izod impact strength of the CKCF carbon coconut composites drastically increases from 268J to 276J as the filler content increases. This fared better than CRCF and CYCF composites. Particle size, shape and carbon surface properties are most likely to influence this trend.

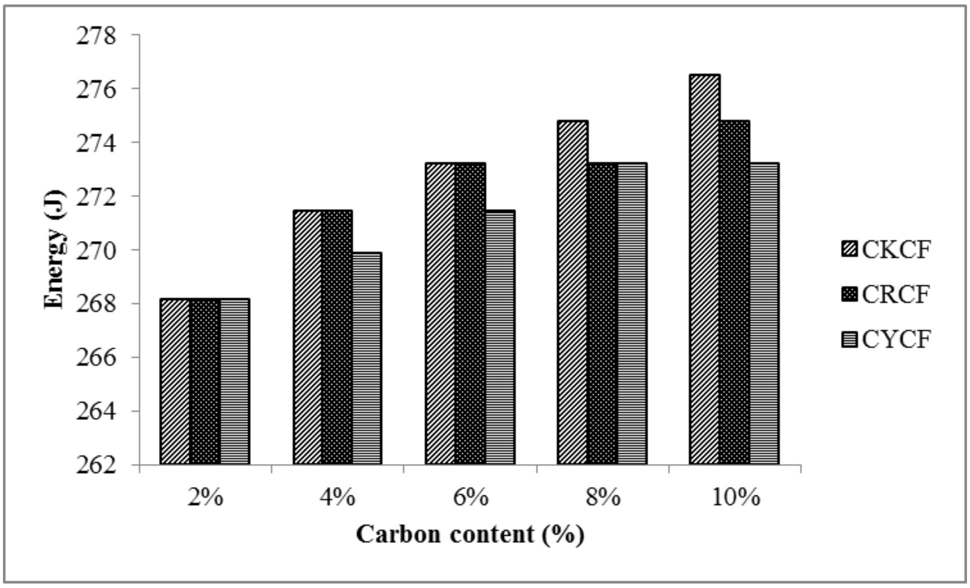
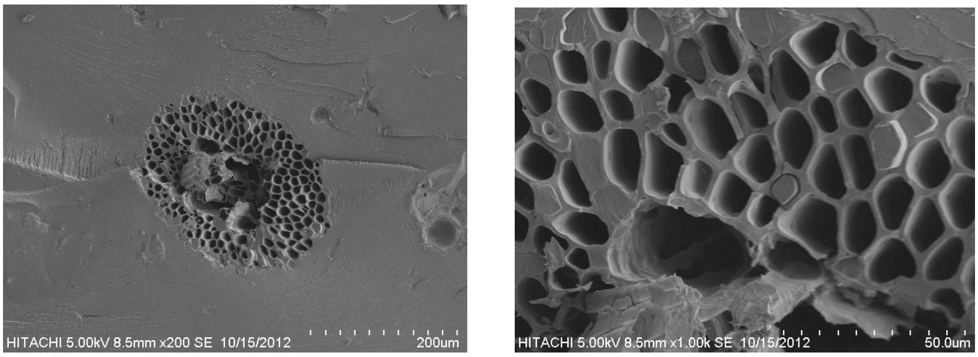


Figure 4. Izod impact strength for CKCF, CYCF and CRCF composites.

In order to study the morphology and interfacial adhesion of filler with matrix of composites, SEM studies were carried out. Microphotographs of the selected samples of CKCF carbon composite are shown in Figure 5. SEM studies were only conducted on the CKCF samples as this exhibited better mechanical strength than the CYCF and CRCF composites. In both cases, surface features and regions of internal and external structures can be seen, as well as the empty spaces between the particles. Figure 3(a) shows the optical overview at 200μm and Figure 3(b) gives an enlarged overview at 50μm. From the enlarged photo of Figure 3(b), it is evident that the CKCF composite is influenced predominantly by the AC (activated carbon) content in the epoxy resin. This is also supported by the fact that the tensile stress averages 11.80MPa, even when carbon content is increased, which is higher than the CRCF and CYCF composites. Moreover, the impact strength value also increased drastically for increased carbon contents from 2 wt.% to 10 wt.%.

In Figure 3(b), cellulose that contains macrofibrils (individual microfibers) can be seen clearly. This further confirms the fact that the strength of the composite is provided by macrofibrils which were held together to form a fiber (Ishak, Sapuan, Leman, Rahman, & Anwar, 2012). It was observed that, even though coir fibers had already converted to ash during the burning process, the structured macrofibrils of the CKCF carbon fibers still remained in the composite layer, thus making it stronger than the CYCF and CRCF composites. This observation is also supported by the study conducted by Reddy and Yang in which they stated that cellulose is the main structural component that provides the mechanical strength to the fibers of the composite (Reddy & Yang, 2005).



(a) (b)

Figure 5. SEM micrograph for samples (a) CKCF 10wt.% at 50μm; (b) CKCF 10wt.% at 200μm.

Figure 6. Differences in length of specimens after creep testing.

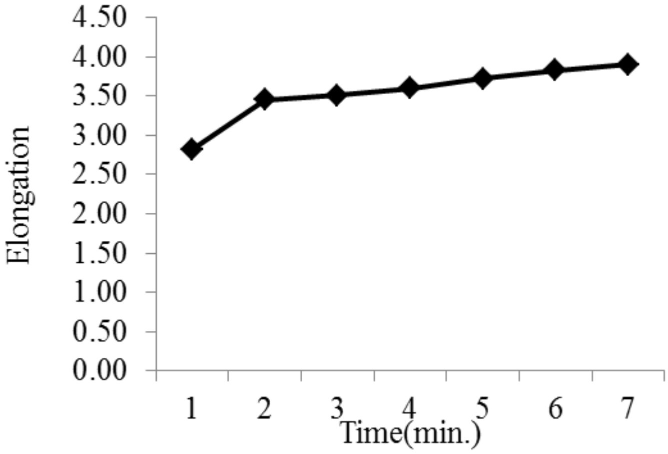


Figure 7. Creep test elongation time (minute)

During the creep test, a load capacity of 2N was used at a temperature of 60°C. The applied load transferred by shear to fibers may exceed the fiber/matrix interfacial bond strength, causing de-bonding to occur. When the stress level exceeds the fiber strength, fiber fracture occurs at the end of elongation after 7 minutes. High strain rates or impact loads may be expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by the usual design parameters, but by its impact or energy absorbing properties. Figure 6 shows the photo of specimens after creep testing, comparing (a) the initial length of the specimen with (b) its length after creep testing. The initial length was 115 cm and the final length was 118 cm, an increase of 3 cm. The results of the creep test on komeng coconut carbon coir fiber composites is presented in Figure 7, where it can be observed that the fiber's elongation depends on the duration of the test.

CONCLUSION

In conclusion, CKCF carbon composite exhibits better mechanical strength than CYCF and CRCF carbon composites. From the results obtained, the impact strength of the samples, especially CKCF carbon composite, increases when the activated carbon (AC) content is increased. The CKCF composite has the highest impact test value at 277J. The CYCF composite exhibited a higher initial tensile stress at 14.73MPa, but the CKCF has a higher average tensile stress at 11.80MPa. Meanwhile, from the creep testing result, it can also be seen that the material will continue to deform slowly with time either indefinitely or until rupture or yielding causes failure. Figure 7 shows the primary region in the early stage of loading, when the creep rate decreases rapidly with time. Then it reaches a steady state which is called the secondary creep stage, followed by a rapid increase (tertiary stage) and fracture area.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Ministry of Higher Education (MOHE) for providing the research grant (FRGS/2/10/TK/UNIKL/03/2). The authors also wish to acknowledge the Department of Mechanical Engineering, Faculty of Engineering, Universiti Putra Malaysia, for providing the required facilities and assistance.

REFERENCES

Abdullah, S., Al-Asady, N. A., Ariffin, A. K., & Rahman, M. M. (2008). A review on finite element analysis approaches in durability assessment of automotive components. *Journal of Applied Sciences*, 8(12), 2192-2201.

Bachtiar, D., Sapuan, S. M., & Hamdan, M. M. (2010). Flexural properties of alkaline treated sugar palm fibre reinforced epoxy composites. *International Journal of Automotive and Mechanical Engineering*, 1, 79-90.

Bledzki, A. K., Mamun, A. A., & Volk, J. (2010). Barley husk and coconut shell reinforced polypropylene composites: The effect of fibre physical, chemical and surface properties. *Composites Science and Technology*, 70(5), 840-846.

Eichhorn, S., Baillie, C., Zafeiropoulos, N., Mwaikambo, L., Ansell, M., Dufresne, A.et al.Groom, L. (2001). Review: Current international research into cellulosic fibres and composites. *Journal of materials Science*, 36(9), 2107-2131.

Ishak, M., Sapuan, S., Leman, Z., Rahman, M., & Anwar, U. (2012). Characterization of sugar palm (arenga pinnata) fibres. *Journal of thermal analysis and calorimetry*, 109(2), 981-989.

Jeffrey, K. J. T., arlochan, F., & Rahman, M. M. (2011). Residual strength of chop strand mats glass fiber/epoxy composite structures: Effect of temperature and water absorption. *International Journal of Automotive and Mechanical Engineering*, 4, 504-519.

Mohanty, A., Misra, M., & Hinrichsen, G. (2000). Biofibres, biodegradable polymers and biocomposites: An overview. *Macromolecular Materials and Engineering*, 276(1), 1-24.

Monteiro, S. N., Lopes, F. P. D., Ferreira, A. S., & Nascimento, D. C. O. (2009). Natural-fiber polymer-matrix composites: Cheaper, tougher, and environmentally friendly. *Jom*, 61(1), 17-22.

Ravi Sankar, H., Srikant, R. R., Vamsi Krishna, P., Bhujanga Rao, V., & Bangaru Babu, P. (2013). Estimation of the dynamic properties of epoxy glass fabric composites with natural rubber particle inclusions. *International Journal of Automotive and Mechanical Engineering*, 7, 968-980.

Reddy, N., & Yang, Y. (2005). Biofibers from agricultural byproducts for industrial applications. *TRENDS in Biotechnology*, 23(1), 22-27.

Sapuan, S., Harimiand, M., & Maleque, M. (2003). Mechanical properties of epoxy/coconut shell filler particle composites. *Arabian Journal for Science and Engineering*, 28(2), 171-182.

Satyanarayana, K., Pillai, C., Sukumaran, K., Pillai, S., Rohatgi, P., & Vijayan, K. (1982). Structure property studies of fibres from various parts of the coconut tree. *Journal of materials Science*, 17(8), 2453-2462.

Schuh, T. G., & Gayer, U. (1997). *Automotive applications of natural fiber composites*. Botucato, Brazil: Unesp Publishers.

Venkataswamy, M., Pillai, C., Prasad, V., & Satyanarayana, K. (1987). Effect of weathering on the mechanical properties of midribs of coconut leaves. *Journal of materials Science*, 22(9), 3167-3172.