23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

EFFECTS OF HIBRIDIZATION ON POLYMERIC COMPOSITES REINFORCED WITH LICURI PALM STRAW FIBERS SUBMITTED TO ACCELERATED ENVIRONMENTAL AGING

Mirtânia Antunes Leão
Rafael Pacheco Evangelista
Sônia Regina Sales Barbosa
IFBA - Federal Institute of Education, Science and Technology. Rua Emídio dos Santos, s/n, Barbalho, Salvador-BA, Brazil.
mirtanialeao@gmail.com; rafaelevangelista87@gmail.com; soniareginacefetba@yahoo.com.br.

Eve Maria Freire de Aquino
UFRN – Federal University of Rio Grande do Norte. Avenida Senador Salgado Filho, 3000, Lagoa Nova, Natal-RN, Brazil.
eve@dem.ufrn.br.

Abstract. *The gradual replacement of so-called conventional materials by polymeric composites has become an issue of great concern due to their behavior facing adverse environmental conditions. Depending on the application of the materials, study of natural degradation has major importance, especially when it is combined with heat, solar radiation, pollution, static loads or fatigue – conditions that induce material aging with the decrease of its resistance and rigidity properties. This degradation is irreversible and affects not only the material's mechanical properties as well as its visual aspect. For the present study, two laminate composites with ortho-terephthalic polyester matrices, one made of licuri palm straw fiber and another made of the same fiber and fiberglass, were submitted to accelerated environmental aging to study the effects of hybridization on microstructural degradation and dimensional instability of the composite. The morphological degradation due to aging analysis was made through visual observation and microscopic analysis of its microstructure. The plastic material reinforced with licuri palm straw fiber alone exhibited some advantages over the hybrid material when their responses to environmental aging – both on photo-oxidation and microstructural degradation - are compared. The hybridization with addition of fiberglass didn't give satisfactory results face the accelerated environmental aging. If the hybrid composite is to be used in direct exposition to adverse environmental conditions, a special attention is needed to perform appropriated maintenance of the parts built with it.*

Keywords: *Polymer Composites, Hybridization, Accelerated Environmental Aging.*

1. INTRODUCTION

Nowadays the properties combinations through the use of composite materials hit such a significant importance that the future of materials application is based on composites development. Composites are a type of material made of two or more constituents that differ in their shapes and/or chemical composition and that are mutually insoluble.

The use of natural reinforcement in polymeric resins based composites is still a challenge to the researchers of this class of materials. Accordingly with Aquino *et al.* (2007) search for better physical, mechanical and chemical properties in the natural fibers take these researchers to the study of new species that can answer to the increasingly demanding requirements.

One of the major advantages of these materials is that when they are used as structural elements they cause a drop on the structure mass and gains on their mechanical, physical and chemical properties. Moreover, the composite materials give the designers considerable flexibility on the design of structures since they allow the development of materials for specific applications (Freire, 2005).

Accordingly with Mander and Bader (1981), Maron *et al.* (1989) and Fernando *et al.* (1998) the application of composite materials in structures has grown in the last decades also because of the development of new and better manufacturing processes as well as new concepts for the reinforcement fabrics and laminate structures. The fibers used in these materials are usually synthetics and they are not environmentally friendly since they are not biodegradable.

The search for new composites made of natural fibers or a blend of natural and synthetic fibers as reinforcement aims to reduce the impact of these materials on the environment.

The degradation or the change in the polymer properties is a result of different types of chemical reactions that can be whether intra or intermolecular. This degradation can be a depolymerization, oxidation, reticulation crosslinking or bond cleavage process. The degradation can be caused by a number of reasons depending on the material, manufacturing process and its use (de Paoli, 2008).

Recent studies show that the oxidation depends in many cases on the properties of the resin in the layer exposed to the environmental aging and its intensity to the type of reinforcement since the matrix/fiber interface plays a major role in the process.

In this present research two laminate composites with ortho-terephthalic polyester matrices, one made of licuri palm straw fiber and another made of the same fiber and fiberglass were submitted to environmental aging in an accelerated aging chamber to investigate the influence of hybridization on microstructural degradation and dimensional stability of the composite. The structural integrity of the laminates was evaluated through visual analysis and the study of the microstructural degradation of both laminates.

2. MATERIALS AND METHODS

The composite materials used have the structural shape of a laminate, one designed with two layers of unidirectional licuri palm straw fiber fabric (LCL), and the other with five alternate and symmetric fabric layers, three made of fiberglass and two made of unidirectional licuri palm straw fiber (LHVL). Both reinforcement fabrics were impregnated with the ortho-terephthalic polyester resin Novapol L120 with no additional use of styrene. Methyl ethyl ketone peroxide (MEKP) was used as catalyst to cure the material at room temperature.

Eight specimens for each composite type (LCL and LHVL) were submitted to an accelerated aging test to assess the influence of the environment on their degradation. The specimens were placed in a chamber and subjected to the action of UV radiation and heated water vapor during daily and intermittent alternate cycles. The UV radiation cycles took 18 hours long each and the heated vapor cycles took another 6 hours each, for a total test length of 2016 hours accordingly with the ASTM G-53-96 standard.

The smooth face of the specimens that was in contact with the mold during the fabrication process is the one exposed to the chamber controlled conditions. All the other faces are carefully isolated from the exposure. The temperatures, outside and inside the chamber, were measured daily as well as the humidity inside the chamber. The average ambient temperature during the test was 31°C.

The surface degradation on the specimens was qualitatively evaluated through microscopic analysis of their microstructure. The evaluation was made observing the composite visual aspect, e.g. its color variation and the fibers exposition. To check for eventual damages in the matrix or on the matrix/fiber interface a scanning electron microscope (SEM) was used. To best evaluate the surface degradation a comparative analysis was made between the original and the aged faces of the species – both the face directly exposed to the chamber conditions and the one opposed to it. The morphological evaluation (original and aged state) was made using a scanner (HP Photosmart C4280), a microscope (ZEISS), and optical microscope (Olimpus MG) and the SEM TESCAN model.

3. RESULTS

First, the results with the composite reinforced with licuri straw fibers alone are presented. Two degradation mechanisms act simultaneously in the composite: the discoloration of the surface and the loss of mechanical integrity. The first is generally the main evidence of the wear caused by the time to the material (Owen, 1984, *apud* Ribeiro, 2004).

The figure 1 shows a macroscopic comparison between the exposed and the original (non-exposed) faces. The photo-oxidation on the composite laminate reinforced with licuri straw fibers alone is very discreet, and is hard to notice the change in the material color, what is not a common characteristic of lignocellulosic fibers.

The proof that the wear suffered by the laminate surface after accelerated aging is modest is shown on the images obtained by the SEM, as can be seen in figure 2 (a) and (b). They show isolated groove spots where the resin evaporated what confirms the low photo-oxidation rate of the surface.

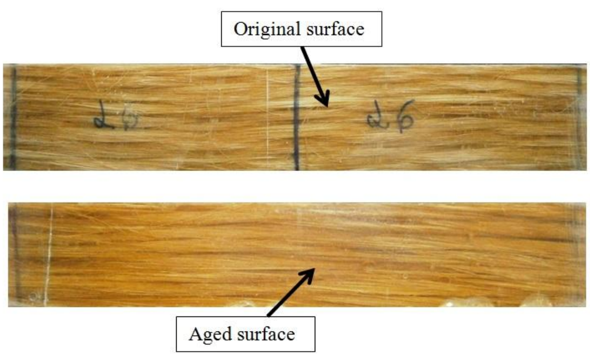

Figure 1. Specimens surfaces exposed to accelerated environmental aging and in the original state.

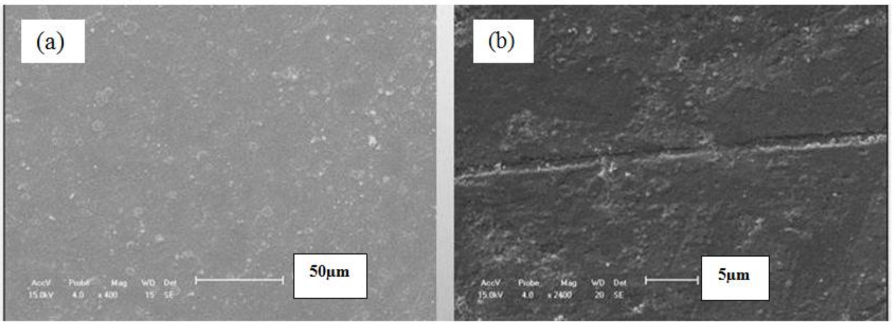

Figure 2. SEM images of the laminate surfaces: a) Surface opposed to aging exposition; b) Aged surface exhibiting a groove.

The next results show the effects of accelerated environmental aging on the composites reinforced with licuri straw fibers and fiberglass. The figure 3 shows a macroscopic comparison between the face exposed to the aging effects and the one opposed to it. It is observed that the color change in the aged surface is small but a noticeable loss of material occurred in the resin matrix.

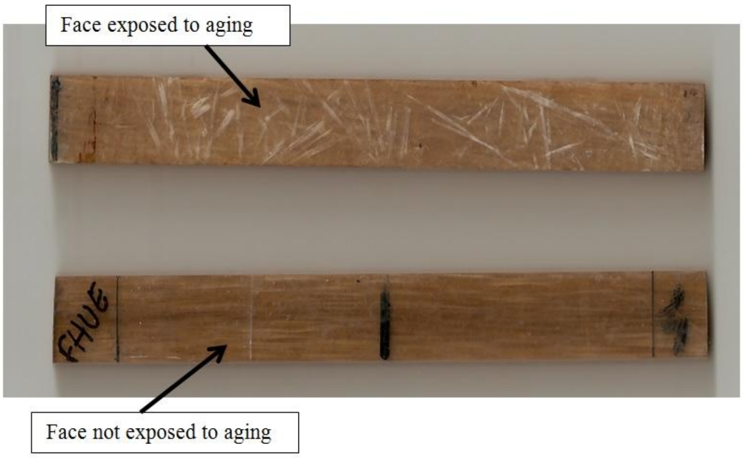

Figure 3. Comparison between the two faces after the accelerated environmental aging test.

For a more detailed analysis on the surface wear the SEM was used and the images are shown in figure 4 (a), (b) and (c). The images show the aged surface was peeled but no fibers were exposed despite the fracture on the matrices (as shown in figure 4c).

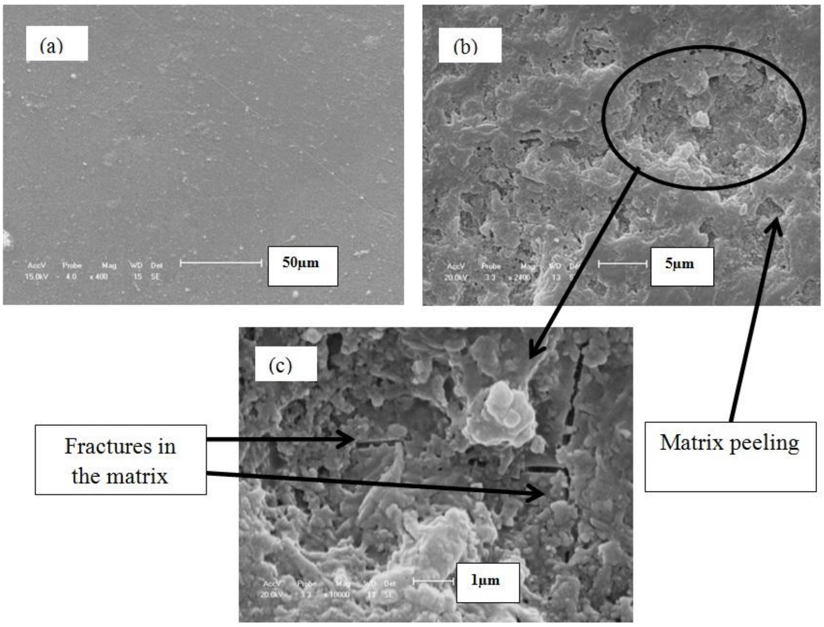

Figure 4. Deterioration of aged hybrid laminate: a) Surface opposed to aging effects; b) Aged surface; c) Magnified SEM image – fracture in matrix with no fiber exposure.

Accordingly to Felipe (2012) the UV radiation is responsible for the color changing in matrix (photo-oxidation) and also the visualization and loss of fiberglass due the resin degradation and the adherence loss or fiber/matrix interface degradation. The degradation process during the accelerated environmental aging starts with the humidity migration in the matrix/fiber interface causing its weakening. The UV radiation makes the interface even more fragile, making it brittle; since alternate temperature cycles happen when the humidity starts to condense it cleans the material in contact; finally the brittle resin is easily removed from the specimen's surface leading to a loss of resin and consequentially a loss of fibers.

4. CONCLUSIONS

The results obtained show that the hybrid laminate suffered a strong deterioration when compared to the wear on the laminate reinforced with licuri straw fibers alone. The side of the hybrid laminate reinforced with fiberglass was the one directly exposed to the environmental aging and it exhibited peeling in its matrix due the loss of resin, showing that the hybridization does not increase the composite resistance to environmental degradation. If the hybrid material is to be used in direct exposure to a hostile environment they will need more careful maintenance if compared with the composite reinforced with licuri straw fiber alone or demand another material to make the hybrid composite.

5. REFERENCES

Aquino, E. M. F., Rodrigues, L. P. S., Oliveira, W; and Silva, R. V., 2007. "Moisture Effect on degradation of Jute/Glass Hybrid Composites". *Journal of Reinforced Plastics and Composites*, Vol. 27, No. 1, p. 219-233.

Freire Jr., R. C. S., 2005. *Fadiga de Alto Ciclo em Compósitos de PRFV. Modelagem por RNAS e Prevenção de Falhas*. Ph.D. thesis, Federal University of Rio Grande do Norte, Natal.

Mander, P.W., Bader, M.G., 1981. "The Strength of Hybrid Glass/Carbon Fiber Composites: Part 1: Failure Strain Enhancement and Failure Mode". *Journal of Materials Science*, Volume 16, Issue 8, p. 2246-2256.

Fernando, G.; Dickson, R.F; Adam, T.; Reiter, H.; Harris, B., 1998. "Fatigue Behavior of Hybrid Composites: Part 1: Carbon/Kevlar Hybrids". *Journal of Materials Science*, Vol. 23, p. 3732-3743.

Maron, G., Harel, H., Neumann, S., 1989. "Fatigue Behavior and Dependent Properties of Aramid Fiber/Carbon Fiber hybrid Composites". *Composites*, Volume 20, Issue 6, p. 537-544.

De Paoli, M. A., 2008. "Degradação e Estabilização de Polímeros". 1 Aug. 2011. Disponível em: <http://www.chemkeys.com/blog/wp-content/uploads/2008/09/polimeros.pdf>.

Owen, 1984 apud Ribeiro, K. C. de A., 2012. *Biocompósitos Poliméricos: Envelhecimento Ambiental, Integridade Estrutural e Processo de Reciclagem*. Ph.D thesis, Federal University of Rio Grande do Norte, Natal.

Felipe, R. N. B., 2012. *Efeitos da Radiação UV, Temperatura e Vapor Aquecido nos Compósitos Poliméricos: Monitoramento, Instabilidade Estrutural e Fratura*. Ph.D. thesis, Federal University of Rio Grande do Norte, Natal.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.