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ENVIRONMENTAL AGING IN POLYMERIC COMPOSITES USING CURAUÁ FIBER

Renata Carla Tavares dos Santos Felipe
Raimundo Nonato Barbosa Felipe
IFRN – Instituto Federal Rio Grande do Norte, Avenida Senador Salgado Filho, 1559, Tirol. Natal-RN, CEP 59015-000
Renata.felipe@ifrn.edu.br
Raimundo.felipe@ifrn.edu.br

Ana Claudia de Melo Caldas Batista
UFERSA – Universidade Federal do Semi-Árido, Campus Caraúbas, RN 233, km 01, Sítio Esperança II, Zona Rural - Caraúbas – RN/Brasil, CEP: 59.780-000.
Ana.batista@ufersa.edu.br

Eve Maria Freire de Aquino
UFRN – DEM – Programa de Pós-graduação em Engenharia mecânica/PPGEM - Centro de Tecnologia, Campus Universitário, Lagoa Nova, Natal – RN/Brasil, CEP: 59072-970
eve@dem.ufrn.br

Abstract. *Natural fibers distinguishing themselves by the increase in implementing as reinforcement in polymer composites to replace synthetic reinforcements because its advantages such as biodegradability, low cost, low density, good toughness, good thermal properties and reduced use of instruments for its treatment or processing. Among these, it's possible to highlight the use of Curauá fiber, which has excellent mechanical strength (when compared with other natural fibers) and it is from the Amazon, have a high potential for agriculture and can improve the social and economic development. However, study of analyze the influence of the environmental aging, characterized in controlled environmental conditions of heated steam and ultraviolet radiation, is still relatively poorly. To understand the effect of environmental aging in composite with Curauá fiber were developed two polymeric composites, both with seven layers, one consisting only short glass-E fibers and the other of the hybrid type reinforced with short glass-E/Curauá fibers, the fiber used was the variety called purple Curauá, provided the Embrapa Amazônia. The materials were exposed to alternating cycles of UV radiation and heated steam. At the end of the exposure period the specimens were evaluated for structural stability by measurement of thickness variation technique and the measurement of mass variation technique. For the techniques used was detected loss thickness and mass for both aged laminates, this being higher loss in the hybrid laminate, justified by the presence of natural fiber Curauá without surface treatment, thus containing impurities on the fiber surface and being more susceptible to this degradation process.*

Keywords: *Hybrid polymer composite, structural instability, accelerated environmental aging.*

1. INTRODUCTION

The discovery of new materials has been growing due to technological advances and market demands. Among these materials, we can highlight the composite materials, in particular, fiber reinforced plastics (PRF), which have gradually gained space in application where conventional materials were used, for example steels. The main advantages of composite materials for designers is the flexibility in the design of structures, as they allow the development of materials for specific applications (FREIRE JR., 2005).

Among the conventional applications, stands out the use of polymeric composites reinforced with glass fibers for tanks and pipes applications. Mariatti e Chum (2005) point to growing demand in applications of reinforced plastics with glass fibers in industries, especially in humid environments, such as water tank and sewage tank because of its excellent resistance to water. Therefore, these materials require good weather resistance.

Highlighting the natural fibers, the Curauá fiber is attracting great interest because be grown in a sensitive area on environmental issues in the Amazon, and may represent a great economical alternative to replace the exploitation of the rainforest, it can still be cultivated in large-scale in Indian reservations.

In composite materials with applications in mechanics, it is common for structures and equipment to be operated under adverse conditions, which significantly affect the performance of equipment manufactured with, for example, fiber reinforced plastics, whose physical and structural properties undergo several types of degradation, such as loss of dimensional stability, interfacial degradation, loss of mass, loss of structural properties and changes in the mechanism of damage. Batista et al. (2006) stands out as an interesting engineering problem, since various equipment such as pipes and tanks were exposed to the environment (not being in covered environments) and thus exposed to bad weather, such as rain and sun. Several researchers seek to verify the influence of weathering on the mechanical behavior of composite materials (BATISTA et al., 2016; JOSEPH et al., 2002; SHIN et al., 2003; PETERSON et al., 2008; SHARMA et al., 2007; FELIPE et al., 2012) . Highlight be given to the authors who study the influence of the environmental aging process on the mechanical response (strength, stiffness, fracture) of these materials (BATISTA et al., 2016 and FELIPE et al., 2012).

It is in this context, the present work develops a methodology for monitoring the entire process of structural degradation of materials under a process of environmental aging process in two PRF laminates.

2. EXPERIMENTAL PROCEDURE

2.1. Manufacture of Composite Laminates

The Novapol ortho-terephthalic (L-120) unsaturated polyester resin was used as a matrix and the reinforcements used were: short fibers of glass-E, and the other a hybrid type reinforced with fibers of glass-E/ fibers of Curauá purple. Two laminates were developed, one consisting of 7 layers also reinforced with short fibers of glass-E (denominated L7) and a hybrid laminate with 4 layers with short fibers of glass-E and 3 layers with unidirectional fibers of Curauá (denominated LH7), both were laminated with a thickness of approximately 6 mm (see Fig. 1). The laminates, with seven layers, was choiced due the fact that it is a typical configuration for the manufacture of tanks and pipes. Both laminates consisting of seven layers and a thickness were around 6 mm.

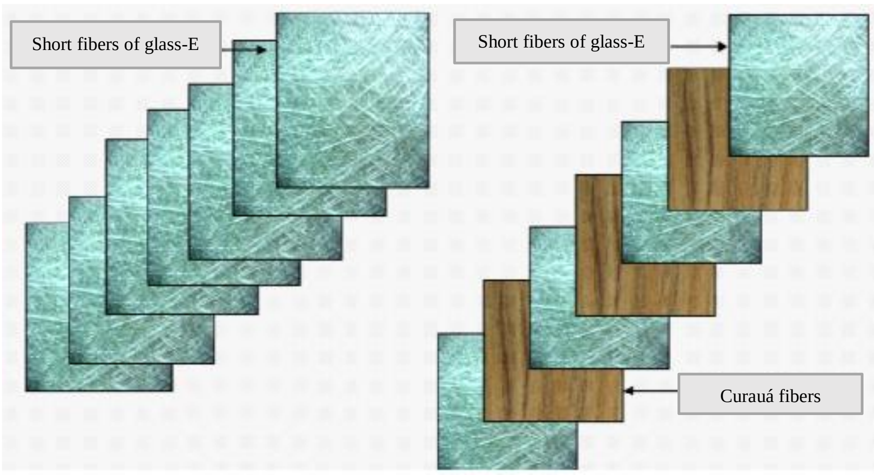

Figure 1. Laminates configurations.

2.2 Aging Test and specimens

The specimens were removed from the laminates mentioned and submitted to environmental ageing accelerated by an aging chamber (Fig. 2). To study the monitoring and modeling of degradation, the aging cycles to which the lamina was exposed: an alternating cycles of UV radiation and a heated steam, for a period defined by standard.

The composites were submitted to environmental aging, and accelerated in an aging chamber that uses the cyclic action of UV rays and heated water vapor. All test specimens were tested in alternating daily cycles of UV radiation (18 h) and heated water vapor (6 h) until reaching the time defined by ASTM G154 (2006). The tested lasted 2016 h (1512 h of UV radiation and 504 h of heated water vapor). The chamber was built in accordance with ASTM G53 (1996).

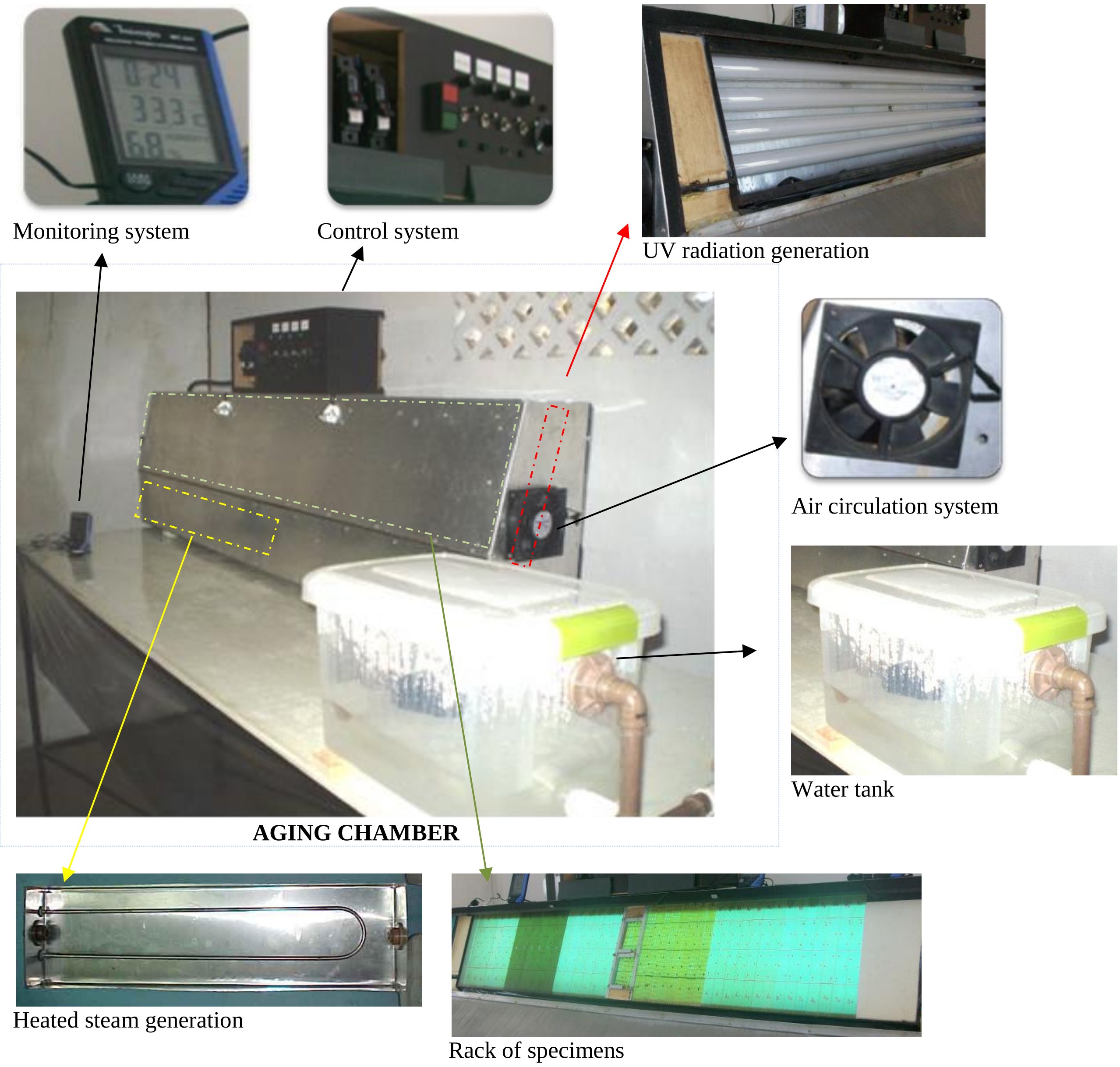

Figure 2. Environmental accelerated aging chamber.

2.3 Analysis of the effect of the photo oxidation process

For characterization of surface degradation (surface directly exposed to aging) the study of the photo-oxidation process was carried out through a comparative analysis of the surfaces of the specimens before being exposed to environmental aging, in the middle of the exposure cycle and after the end of their exposure. Analysis of the photo-oxidation process on the surfaces of the specimens was performed using macroscopic analysis; the images were obtained on the HP Photosmart C4280 scanner.

2.4 Structural stability evaluation of laminates

At the end of the exposure period, the specimens were subjected to a structural stability assessment by means of the developed Measurement of Thickness Variation Technique (MTVT) and the Measurement of Mass Variation Technique (MMVT).

The MMVT was based on Fick's Broadcasting law and the calculations were carried out using Eq. (1).

$$\Delta M = \frac{M_{ageing} - M_{original}}{M_{original}} \tag{1}$$

Where M_{ageing} is the mass of the aged specimen (g) and $M_{original}$ the mass of the specimen in its original condition (g).

Mass variation was measured based on pre-established weighing (before the ageing process), that is, specimens were removed from the aging chamber and replaced after being weighed on a balance. The thickness the variation was measured based on pre-established thickness (before the ageing process), that is, specimens were removed from the aging chamber and the new thickness is measured with a micrometer. The technique evaluates the variation of thickness suffered in the specimens from the measurement of 48 points (6 measurements in each specimen, total of 8 specimens), see a specimen example in Fig. 3.

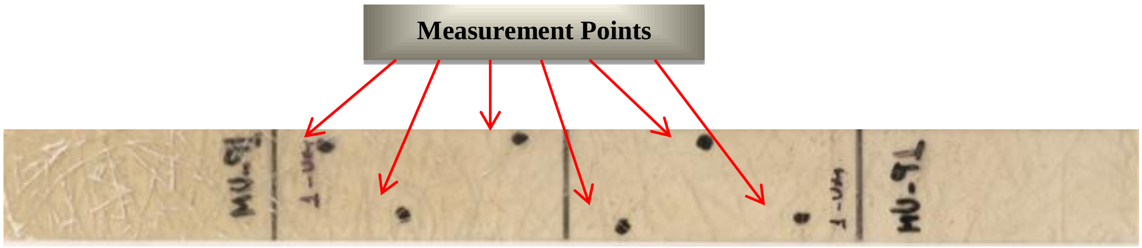

Figure 3. Example of thickness monitoring points.

3. RESULTS AND DISCUSSION

3.1 Photo-oxidation process

About the photo-oxidation process (Fig. 4), the results shows that the surface wear occurred in the L7 and LH7 composites after the total aging during the aging tests was evaluated qualitatively involving color variation analyzes, that is, considering the visual appearance of the composite.

TEMPO DE ENVELHECIMENTO			
Specimens	**Original**	**35 days**	**84 days**
L7			
LH7			

Figure 4. The photo-oxidation process that occurred in the laminates composites - L7 and LH7.

Through the electronic scanning process, a monitoring was done throughout the aging period, in the initial time and in the periods of 35 and 84 days of aging. Since the 35 days of exposure (840 h) it is possible to verify the color variation, making the surface opaque, for both laminates (L7 and LH7), this color variation happens exactly due to the degradation process of photo-oxidation of the matrix. Analyzing the samples after the aging period for an exposure time of 84 days (2016 h), the appearance of the glass fibers for both the L7 and LH7 samples, caused by matrix loss, is detected; and in addition, the increase in the number of exposed fibers increases until the end of the test. The same phenomenon occurred in the work of Felipe et al. (2012), obtained for a short glass fiber sheet impregnated with polyester resin.

3.2 Evaluation of structural stability of composite laminates

In order to quantify the structural stability of the proposed laminates exposed to aging, the results obtained in the MMVT and the MTVT will be exposed separately.

3.2.1 Measurement of Mass Variation Technique – MMVT

The Measurement of Mass Variation Technique (Fig. 5) shows that the behavior of the loss of mass as a function of time shows that the specimens began to lose mass at different times of aging. For the L7 specimens the mass loss occurred from 400 h of exposure while for the LH7 composite laminate the mass loss started at 200 h of exposure.

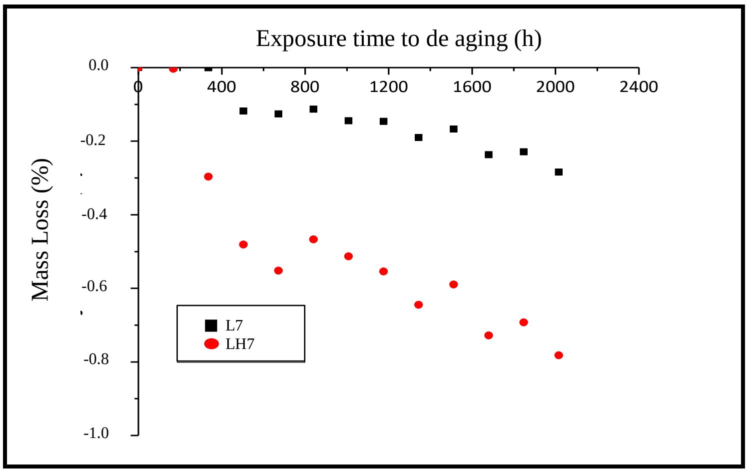

Figure 5. Composite mass loss during accelerated aging.

As the resin was the same for the two composite laminates, the only influence is the susceptibility of natural Curauá fiber, relative to humidity and temperature. The composite laminate LH7 degradation occurred more intensely than the L7 composite, the mass loss value reached about three times the value obtained with L7. The mass loss (Fig. 6) at the end of the process was 0.28% and 0.78% for L7 and LH7, respectively. Highlight that percentage variation was determined in relation to the mass data of the test bodies in the original condition.

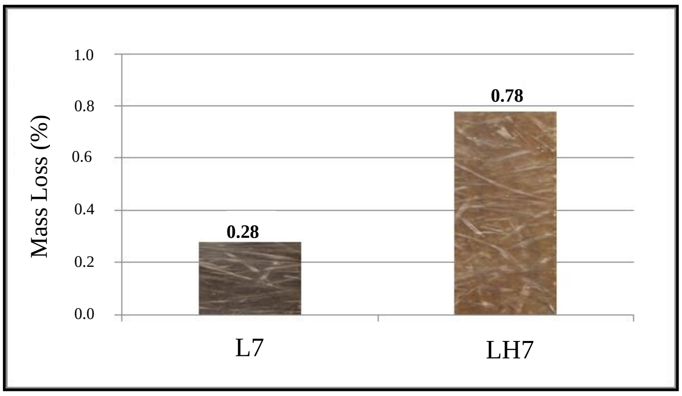

Figure 6. Variation of mass (percentage) of the test specimens - L7 and LH7.

3.2.2. Measurement of Thickness Variation Technique - MTVT

The thickness loss values for the L7 and LH7 laminates after the end of the environmental aging are recorded in Tab. 1.

Table 1. Laminate composites thickness loss after the accelerated aging.

Laminate	Average Variation (µm)	Standard deviation (µm)
L7	14,4	±4,5
LH7	44,8	±10,6

Analyzing the values presented for thickness variation in the L7 and LH7 specimens, it is observed that the aging process affected the structural integrity much more strongly in the LH7 composite than in the L7 composite, probably due to the presence of the natural fiber of Curauá, which is more susceptible to temperature variation in relation to fiber shrinkage mainly due to the presence of lignin in the fiber (LEDO, 2005). The presented values of the thickness variation of the LH7 specimens are three times higher than that of the L7 laminate (Fig. 7).

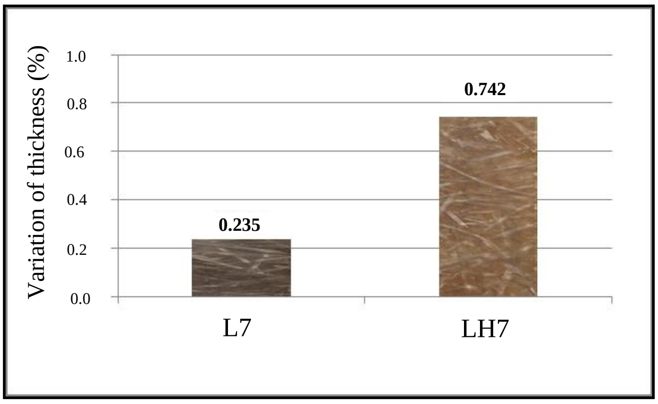

Figure 7. Variation of thickness (percentage) of the test specimens - L7 and LH7.

With respect to the hybrid composite laminate (LH7), it was evidenced that the superficial wear on the outer layer, which was a short glass fiber, was not the only one responsible for the decrease in laminate thickness. The other reinforcing component responsible for the hybridization of the composite which was the curauá fiber, had a considerable share of responsibility in this phenomenon, probably being able to decrease the diameter of the fiber, after exposure to environmental degradation by the aging condition (UV radiation, temperature and heated steam), parameters responsible for changes in the physical properties of curauá fiber.

3.2.1 Comparison: MMVT x MTVT

For the analysis of the comparative, it is highlighted that the degradation measured by the MTVT presented a percentage variation approximated to that obtained by the MMVT technique, which indicates consistency in the obtained data and being possible to be applied, these techniques, under satisfactory conditions in the monitoring of structures of plastics reinforced by glass fibers in environmental conditions close to the research carried out. As previously noted, the percentage difference of both MMVT and MTVT had the same result: wear of LH7 was the equivalent of 3 times the wear suffered by L7.

4. CONCLUSION

With this work, it was possible to conclude that:

- The environmental aging process influenced the structural degradation of both materials proposed for study (**L7** and **LH7**);
- The thickness and mass loss for both composite laminates (**L7** and **LH7**) were detected when using the techniques (measurement of thickness variation technique and thickness variation technique);

- The highest loss for both techniques occurred in the hybrid laminate, justified by the presence of the natural fiber of curauá without surface treatment, consequently, containing impurities on the fiber surface and becoming more susceptible to the degradation process; and
- The degradation measured by the two techniques presents coherence in the results, being possible then its use in the monitoring of structures manufactured in PRF.

5. ACKNOWLEDGEMENTS

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