International Journal of Mechanical and Production Engineering, ISSN(p): 2320-2092, ISSN(e): 2321-2071
Volume- 8, Issue-2, Feb.-2020, http://iraj.in

STUDY OF THE PROPERTIES OF THE SELF-REINFORCED COMPOUND OF POLYLACTIC ACID AND AN AMAZON FIBER

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Abstract - This paper presents the study of the mechanical properties of a self-reinforced composite material based on polylactic acid and an Amazonian fiber. Many of the research and developments on composite materials reinforced with natural fibers have been very attractive to different research groups in recent years, due to their good characteristics and multiple applications. Being the production of these materials capable of achieving an impact in different fields of knowledge, since their benefits from the environmental point of view manage to make environmentally friendly compounds to achieve their economic impact since they create lighter structures and of origin from renewable sources . It seeks to present these composite materials as an alternative to polymers for commercial use such as Polypropylene (PP), Polyethylene Terephthalate (PET), Polystyrene (PE) among others, which come from petroleum derivatives. The methods used to achieve the characterization of composite materials were as follows:
Yanchama (natural fiber): it was cut, spun, dehydrated and heavy.
Polylactic acid (PLA): heavy, treated (matrix), cut.
It was obtained that the best sample of this study was that of longitudinal spun red yanchama (YC + PLA (L)), because it had a better mechanical behavior, which indicates that this sample had a greater strain stress (4,006 MPa), higher deformation percentage (5.33%) and higher Young's modulus (37.48).

Keywords - Polylactic Acid (PLA), Amazon Natural Fiber, Yanchama, Self-Reinforced Compounds .

List of Abbreviations

YB: white yanchama. YC: red yanchama. PLA: polylactic acid. PLAYB: composite based on white yanchama reinforced with PLA threads. PLAYC: composited of red yanchama reinforced with threads of PLA. L: longitudinal direction of reinforced natural fiber with threads of PLA. T: cross reinforcement by natural fiber with PLA threads. YB-PLA (L): white yanchama composite without PLA reinforcement arranged longitudinally. YB-PLA (T): white yanchama composite without PLA with cross reinforcement. YB + PLA (45): white yanchama composite with PLA reinforcement in threads arranged at 45 ° from the fiber weft. YB + PLA (L): white yanchama composite with PLA reinforcement in threads arranged longitudinally. YB + PLA (T): white yanchama composite with PLA reinforcement in threads in cross arrangement. YC + PLA (45): red yanchama composite with PLA reinforcement in threads arranged 45 ° from the fiber weft. YC + PLA (L): red yanchama composite with PLA reinforcement in threads arranged longitudinally. YC + PLA (T): composite based on red yanchama with reinforcement of PLA in threads in cross arrangement.

I. INTRODUCTION

The bioplastics market is growing every year due to the great advantages they offer to the environment [1]. In recent years, global production is expected to increase to more than 7.8 tons in the period of 2019, which indicates that biodegradable bio-based polymers represent 84%, while non-biodegradable polymers are the remaining 16% [1]. Within bioplastics, polylactic acid (PLA), obtained from beets or corn, has been in greater demand due to its bio-degradability, bio-reabsorption and biocompatibility[2]. PLA is one of the most favorable compounds because is considered as a synthetic polymer (biomaterial) in terms of tissue engineering and surgical line [3] this is possible due to its mechanical properties such as biodegradability, among others [4]. Biodegradable polymers derived from natural resources are increasingly receiving attention due to the increase in environmental awareness, since this has a negative impact of excessive use of petroleum-derived polymers, such as so-called commodities: Polyethylene Terephthalate (PET), Polypropylene (PP), Polystyrene (PE),etc. [5].

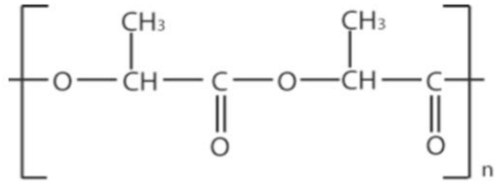

Fig. 1. Chemical Structure of Polylactic Acid (PLA) .

Among the various applications of polymers, it is clear their increasing use in the design of structures in which they are used as reinforcement, once they have multiple advantages compared to traditionally used materials, such as low density, strength, renewable, and good thermal insulation [6]. Usually, they are used as matrices of reinforcing materials, because they offer advantages as an opportunity for recycling and manufacturing of light structures [7]. Finally, the composite materials based on a polymer and a natural fiber have low cost and good mechanical properties, which is attributed to their resistance to corrosion and chemical agents [8].

Property	Value
Density (g/mL)	0,44[a] – 0,89[b]
Diameter (mm)	0,4 – 0,074[b]
Humidity (%)	8,36[b]
Water absorption (%)	29,67[b]
Modulus of elasticity in flexion (Kg/cm2)	79000[a]
Flexion break modulus (Kg/cm2)	500[a]
Maximum tensile strength(KN/cm2)	0,132-0,517[b]
Parallel compression (Kg/cm2)	288,00[a]
Perpendicular compression (Kg/cm2)	36,00[a]
Parallel cut to the fibers (Kg/cm2)	69,00[a]
Hardnesson the sides (Kg/cm2)	283,00[a]
Tenacity (shock resistance) (Kg-m)	1.90[a]
Relationship T/R	1.50[a]

Table 1. Properties of yanchama fiber. a: [9]; b: [10].

The objective of this work was to obtain a composite from a natural fiber (yanchama) and polylactic acid (PLA) and its physical and chemical characterization allowed proposing applications in structural materials.

II. MATERIALS AND METHODS

In the preparation of the compound, there were YB and YC fibers that were purchased directly from the Tikuna indigenous population of the Amazon, Colombia. On the other hand, the polymer matrix was obtained from PLAp pellets was kindly provided by Nature works ® REF 3051D with a molar mass of 1.25 g / mol, melting temperature of 150 °C and was used without additional treatments. The PLA used as fiber reinforcement (PLAy) and exhibits a melting point of 171 °C. 4.6 grams of pellets were used in the manufacture of the matrix sheet. It was used a first mold (Figure 2a) of 120 mm x 180 mm x 0.15 mm. Preheating was carried out at 170 °C for 2 min in a hydraulic press (MARSHAL, SE221-1415), exceeding the melting point of the PLAp, and removing the moisture present in the polymer and allowing the polymer to flow until the mold is completely filled. Two pressure ramps were made as follows: (1) 66 psig / 3 min to promote material degassing and (ii) 235 ± 5 psig with 5 min to finish molding. The polymeric matrix was allowed to cool to 50 °C and was removed from the press and reserved at room temperature, obtaining thin films without the presence of bubbles with a thickness of 0.15 - 0.20 mm [1], [13]. Samples of composite materials without self-reinforcement were prepared as follows: it was cut rectangular pieces (Figure 2 c, d, e) of 120 mm x 80 mm of yanchama (n = 3) with a thickness of 0.5 ± 0.8 mm, which were dried inside from the hydraulic press at 120 °C for 10 s to remove the remaining moisture. To obtain the polymer matrix reinforced with natural fiber: the stacking of the sheets was made from polymer matrices and natural fiber (Figure 2 c).

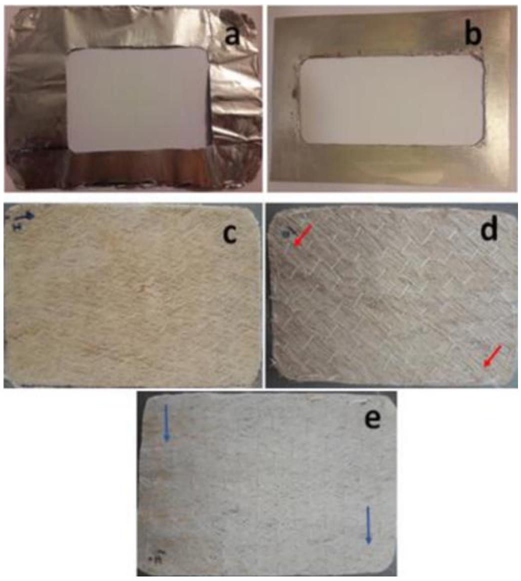

Fig.2. Molds and fibers used in the production of the PLAYB-PLAYC compound. (a) Aluminum mold for the production of polymeric flat matrices of PLA, (b) Steel frame used in the stacking of PLAY, (c) PLAY compound, (d) Yanchama fiber reinforced with PLA threads in transverse direction (cross redarrow), and (e) longitudinally (longitudinal blue arrow).

The samples of self-reinforced composite materials were prepared as follows, the natural fiber pieces of 120 mm x 80 mm x 2 mm were suitable with 2 PLAy threads (Figure 2d,e) sewn crosswise, longitudinally and 45 ° to the direction of bark growth (Figure 3 a, b, c).Then, the stacking of sheets (matrix / fiber / matrix) was performed and finally, they were placed inside a second steel frame 125 mm x 84 mm x 2 mm that was taken to the hydraulic press to preheat to 160 ° C for 2 min. Next, the pressure and heating ramps used to obtain the polymer matrices were followed.

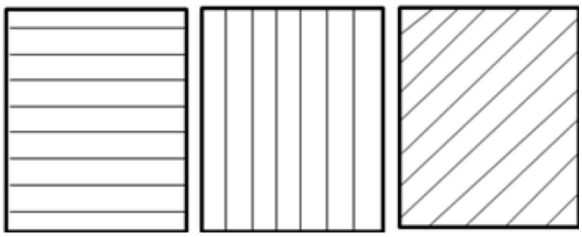

Fig. 3. a: Longitudinal, b: Crossly, c: 45°

For the mechanical properties assessment, at least 5 specimens were used per test. The ASTM D638 standard (type IV test tube) [14] was followed, in order to determine maximum tensile stress, maximum stress-strain, breakage stress and breakage strain in a universal testing machine (Jinan Testing Equipment IE corporation, WDW-30). Finally, the specimens were observed in a stereoscope (LEICA EZ4D). The curves that were obtained were analyzed using the ORIGIN ® v9 software in order to determine the breaking point, maximum tensile stress, maximum stress-strain and breakage strain.

III. RESULTS AND DISCUSSION

For Swolfts et al. [13], composites based on fibers and polymers, can be formed in three ways, depending on the position they occupy in the fabric of the composite. In other words, a composite could be reinforced intra-threads, between vertical layers and between horizontal layers (Figure 4). In this study, the compound obtained PLAY is of the type between vertical layers, because the PLA threads that reinforce the natural fiber were woven crossly, longitudinally and at 45 ° C to the yanchama framework.

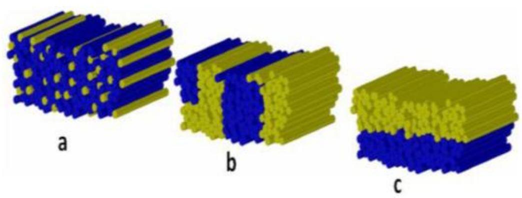

Fig.4. Configurations of fiber composites and intra-thread reinforcements (a), between vertical layers (b) and between horizontal layers (c) [13] .

From Table 2, it is observed that the sample with higher strain-stress value was the longitudinal spun red yanchama (YC + PLA (L)) with 37.48 MPa, this is due to better adhesion interfacial between the matrix and the fibers.

Sample	Young modulus GN/m³	Maximum tensile strength (MPa)	Final deformation %	Fragile (f) or sweet (s) behavior
YB-PLA(L)	14.55	2.126	2.694	s
YB-PLA(T)	35.50	3.728	-	f
YB+PLA(45)	21.82	3.766	-	f
YB+PLA(L)	24.01	3.402	-	f
YB+PLA(T)	9.46	0.958	1.226	s
YC+PLA(45)	9.00	2.118	2.32	s
YC+PLA(L)	37.48	4.006	5.33	s
YC+PLA(T)	7.19	2.422	2.856	s

Table 2. Determination of Young modulus, maximum attraction effort, final deformation, and behavior.

On the other hand, most of the specimens that were tested have the same behavior at the beginning, a ductile behavior with the presence of plastic deformation and strain hardening due to the alignment of the fibers during traction to finally break fragilely. The difference between the behaviors from different samples was given by the reinforcement content in both directions and by the improvement in interfacial adhesion due to the chosen consolidation temperature . It was obtained that the one that showed the highest percentage of deformation was the sample of longitudinal spun red yanchama (YC + PLA (L)), because this sample showed higher ductility value, meaning a better degree of consolidation between the matrix and the fibers. The hardening process is due to the plastic deformation by the rearrangement of the fibers, causing both higher stiffness and resistance to the final tensile. Not all samples showed fracture until the final state that is attributed to a problem of the acquisition system. Finally, analyzing each curve, it was obtained that the sample with the largest Young odulus was the longitudinal spun red yanchama sample (YC + PLA (L)), because this sample presented more rigidity than others did. Considering the above, it can be deduced that the sample with the best behavior and rigidity was longitudinal spun red yanchama (YC + PLA (L)), because the tensile stress, Young modulus and its final deformation were higher. Therefore, this sample was the evidence that itcould verify that composite material based on yanchama and PLA, is a heavy load resistant composite.

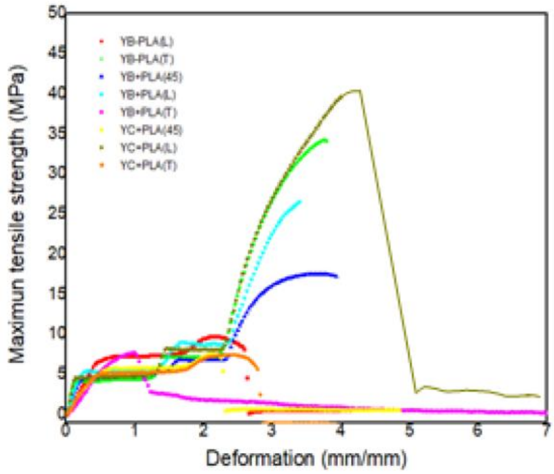

Fig 5. Mechanical properties of the studied composites.

After fracture (Table 5) PLA fibers remained intact due to improved interfacial adhesion between the matrix and the yanchama fibers. For the pictures of table 3 (a, f, h), it can be seen areas of plastic deformation and areas of fragile breakage by cutting of yanchama fibers. For (b, c, d, e, g) it can be observed that these have a fragile behavior because they had a low deformation, so these samples had a high risk of sudden fracture. Their surfaces are usually smooth or amorphous and do not support extended use. The presence of holes on the surfaces of the samples is observed due to two possible causes, one, air bubbles could remain at the time of stacking between the fiber and the matrix (matrix / fiber / matrix), and two, the nature of the natural Amazonian fiber. Several tests were carried out taking into account the white yanchama (without spinning) and the composite (yanchama spun with PLA). Both were compared with each other and thus determine which of these two has better mechanical strength, stiffness and Young modulus. In Figure 5it can be seen how the PLA fibers remain intact, helping to improve inter facial adhesion between the matrix and the yanchama fibers where it enters into the yanchama fibers. On the other hand, samples (d), (g), (c), a ductile behavior is seen because it is easily deformable, which indicates that it was stretched considerably before breaking.

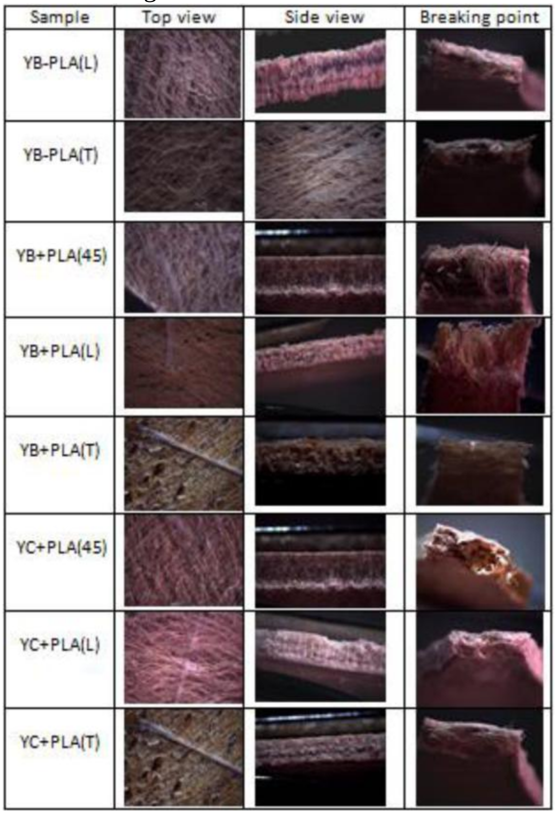

Table 3. Breakage of the test tubes of the compounds (100x).

IV. CONCLUSION

The adhesion of natural fiber (yanchama) with the matrix of polylactic acid (PLA) led to the production of a composite material with good mechanical behavior, at a low cost among others. It can also be noted, that natural fiber can be a good reinforcement of this polymeric material, since it manages to have an improvement in its mechanical behavior. This type of composite materials offer us improved properties in terms of strength, weight and stiffness, which are not usual in the original materials, since these allow us to have better elongation at break, a longer and less damaging service life, etc. Taking into account what was previously studied, it is concluded that the best sample in this work was that of longitudinal spun red yanchama (YC + PLA (L)), because it had better mechanical behavior achieving a very stiffness and resistance good, obtaining a material capable of resisting.

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