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RESEARCH ARTICLE

MECHANICAL CHARACTERISATION OF COMPOSITE MATERIALS MADE FROM WOOD FIBERS OF TALL-PALM AND WASTE PLASTICS

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ABSTRACT

The recovery of plastic waste is an environmental challenge for the world today having regard to the problems of pollution. New alternatives for the recovery of this waste must be found. One possible solution is their use in the design and the realization of wood-plastic composites. This is the aim of our work, which consists to evaluate the properties of the composite made from recovered plastic waste used as a matrix and the fibers of tall-palm (*Borassus aethiopum* Mart., Arecaceae) used as reinforcements. This composite material, constituted by wood fibers and plastic waste, has been designed in the logic of an "eco-material", for structural or decorative use. It is manufactured using a compression process. The physico-mechanical tests carried out have given interesting results.

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INTRODUCTION

This paper has two objectives. One is to contribute to the protection of the environment and public health by ridding it of plastic waste, and the other is to develop composite materials for decorative or structural use using the fibers of tall-palm (Ngargueudedjim et al. IJETR sept 2015;) as reinforcements in the matrix of molten plastic waste, for it is known that composite materials can be made from recycled materials (English et al (1996), Mishra and Naik (1999)) and that the role of the polymer matrix is to distribute the load between the fibers and to ensure assembling and adhesion between them (Haque, 1997). During the melting of plastic waste to obtain the matrix by the plasturgist method, the rise of temperature borders on 180°C. This is not harmful to the materials because the destruction of the crystalline order occurs above 320°C by thermal agitation of the molecules (Kim et al, 2001), although Stamm (1956) observed irreversible degradation effects by heat such as changing of viscosity, increasing of degradation with oxidation. Indeed, thermal degradation is a limiting factor in hot manufacturing processes for wood/plastic composites because most natural fibers lose their rigidity when temperature reaches 160°C and lignin degrades around 200°C.

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A compression casting device, designed and manufactured in the LERTI laboratory, was used to produce the eco-material from molten plastic waste and tall-palm wood. This eco-material was named PLASTTRONIER. Whatever the polymer used, the incorporation of reinforcements (fibers) can modify its physical and mechanical characteristics (Trotignon *et al.,* 1996; Nabi Saheb *et al.,* 1999), because the great variability of the physical-mechanical properties of natural fibers due to their constitutive and anatomical differences (Rowell *et al.,* 1997; Banks and Lawther, 1994) will impact on the characteristics of composites, but generally in an evolutionary way. The reinforcement of a composite material is thus supposed to improve the structural or mechanical properties. Used as a structure, the PLASTRONIER will be subjected to stresses that may lead to its breaking. Studies (Hull, 1981; Naoyuki *et al.,* 1997) have shown that breaking of a wood-polymer composite can be caused either by matrix cracking or by decohesion of the border between reinforcement and matrix (interface), and this depends on several parameters, including properties of matrix and reinforcement, porosity, distribution of fibers in the volume and the quality of the interface between matrix and fibers.

MATERIALS, EQUIPMENT AND METHODOLOGY

Materials

The specimens are made from the so-called "PLASTRONIER" composites, which were obtained by stratification of a matrix layer made from molten plastic waste (Fig.1) to have the "bottom of the casting". On this matrix layer, the reinforcement made from fibers of tall-palm (Duramen), from veins of the leaves (Nervures) or from the woven leaves (Nattes) of tall-palm (Fig.2) is placed; then another molten plastic is poured again. The whole is compressed in the mould by screwing (Fig. 3.b).

This moulding technique known as a compression moulding, is similar to the casting but is applied to pasty or semi-fused materials (thermoplastic granules, pastes and thermosetting granules). The product is compressed in a mould, usually heated, and clamped in a press. After cooling, the object is extracted. Various variants of this process apply to composites. The products manufactured by this process have good mechanical properties, making it possible to obtain rigid and light materials (Michaud, 2003). The fusion of the resin was very slow (about 3 hours). First, 2 kilograms of plastic waste was melted and then 2 kilograms were added each time the first quantity was completely melted. This was done until the entire measured quantity was finished. The time taken to melt each 2 kilograms is about 36 minutes. The melting temperature was not measured. After a cooling down time, demoulding is carried out to remove the "plastrônier". Three types of "plastrôniers" have been developed according the use of reinforcements (fibers of tall-palm wood named Duramen, veins of tall-palm leaves named Nervures and woven leaves of tall-palm na,ed Nattes).

The production of the "PLASTTRONIER" plate required 10 kilograms of resins (PP, PET) and 2 kilograms of reinforcements, i.e. approximately 17% of reinforcements in the sheet. In accordance with the ASTM D790 Standard, six samples (length 360 mm, width 80 mm and thickness 20 mm) were extracted by sawing each type of "plastronier" and subjected to three-point bending on the equipment of LaMCoS laboratory at INSA Lyon in France, which is the SCHENKY 250 traction machine equipped with a 10 kN force sensor. Three-point bending is indicated, according to the ASTM D790 Standard, to characterise this type of material due to the simplicity of its implementation and the good results it can provide. This load provides the deflection and force applied until the specimen breaks.

Equipment

- Gas bottle for melting plastic waste (Fig.4.a)
- Two types of screw moulds to make the plate (Fig.4.a) and cylindrical bars (Fig.4.b)
- SCHENCK 250 traction machine (Fig.5.a), equipped with a force sensor EM10kN (Fig.5.b) and the three-point bending device. The descent speed of the movable bit was set at 1.0 mm/sec.
- Computer (Fig.5.c) for data acquisition (results in terms of forces and deflection)) using the MTS EM Flexion software.

METHODOLOGY

To obtain the test specimens, the panels were cut with a circular saw to the dimensions imposed (length 360 mm, width 80 mm and thickness 20 mm) by the ASTM-D790 Standard which describes the process to correctly perform a 3-point bending until breakage. The deburring and surfacing of the test specimens was done on a fine grain belt grinder.

Three types of samples are obtained and named « Plastrônier_Rameau » (see Fig.6.a), « Plastrônier_Duramen » (Fig.6.b) and « Plastrônier_Natte » (Fig.6.c). The experimental work consists to subject the samples to a 3-point bending. After positioning the specimen and setting the parameters of the SCHENKY 250 traction machine, i.e. the descent speed of the mobile jaw, the machine is started and the mobile jaw is brought closer to the specimen and then allowed to come into contact with the specimen until breakage occurs.

All the specimens were subjected to the 3-point bending test with 320 mm, the distance between the two supports, constituting the span (see Fig.6.d and e) and the results generated by the computer were processed and interpreted.

RESULTS AND DISCUSSION

After pre-treatment work of the results by discarding tests with incorrect values due to problems from settings and positioning of the specimens, the curves of the bending forces according to the variation of the arrows were drawn in Excel for at least three specimens of the "Plastrônier_Duramen", "Plastrônier_ Natte" and "Plastrônier_Rameau" samples

"Plastrônier Duramen" Composite: The maximum bending forces which can be supported by the "plastrônier_Duramen" composite are between 150 and 190 N for deflections going from 4,8 to 6 mm (see Fig. 7 above). The multitude of short and long duramen fibers with 3 mm as size provide very good reinforcement in the molten plastic waste matrix. Roughnesses in these fibers make difficult to remove adhesion at the reinforcement-matrix interfaces. This can be clearly seen in this Figure 1 where, after matrix failure, the composite can supported forces around 150 N with 9 mm of deflection.

"Plastrônier Nattes" composite

The Plastrônier_Nattes composite breaks for forces around 230N and the arrow value is approximately 3 mm (see Fig.8 above). A residual force, 50 N, remains continuous despite the growth of the deflection. This suggests that after matrix rupture, the woven leaves of tall-palm used as reinforcement slips through the matrix since there is decohesion at the reinforcement-matrix interface.

Plastrônier_Rameau Composite: The forces that the Plastrônier_Rameau composite can withstand range from 300 to 350 N for deflections between 2.7 and 3.5 mm and a force level of 50 N (see Fig.9) occurs just after matrix failure due to decohesion between reinforcement and matrix.

Use: As mentioned above, this work should lead to contributing to environmental protection by reusing plastic waste for other purposes. The results given by the tests carried out on the various samples of the "plastrônier" composites show it is possible to use these composites for producing the useful objects, and thus it will absorb certain quantities of plastic waste. As a result of the mechanical characterisation work on the "plastrônier", a tablet and an ornamental horse (Fig.10.a and b)were manufactured. The tablet (see photo 18 below) consumed seven (7) kg of plastic waste and 2.7 kg of reinforcements. The reinforcements in this tablet are ribs from the leaves of tall-palm.

a) PP Waste

b) PET Waste

Figure 1. Waste of polymers

a) Veins of tall-palm leaves

b) Duramen fiber of tall-palmdu rônier

Figure 2. Natural reinforcements from tall-palm

a) Casting	**b) Compression moulding**

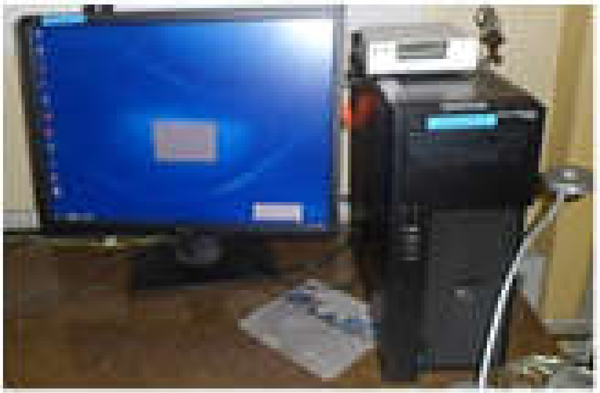
Figure 3. Moulding

a) mould equipped with a gas bottle	**b) Cylindrical bar mould**

Figure 4. Equipments of moulding

a) SCHENCK 250 traction machine

b) Force sensor EM 10kN



c) Data acquisition computer

Figure 5. Test equipments

a) Test specimen « Plastrônier_Rameau »

b) Test specimen « Plastrônier_Duramen »

c) Test specimen « Plastrônier_Natte »

d) Placement of the test specimen

e) breakage of specimen

Figure 6. Samples and test

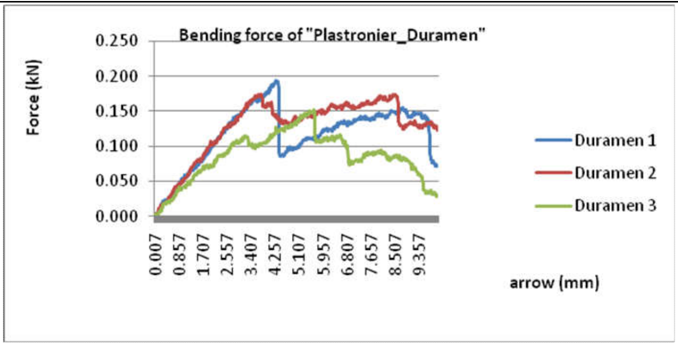


Figure 7. Bending stress - deflection curve of the Plastrônier_Duramen composite

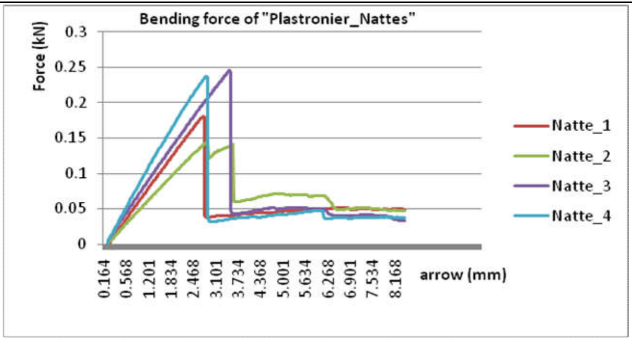


Figure 8. Bending stress - deflection curve of the Plastrônier_Nattes composite

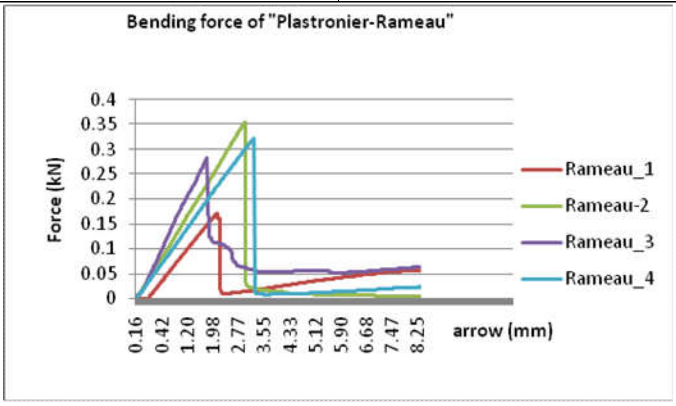


Figure 9. Bending stress - deflection curve of the Plastrônier_Rameau composite

a) Tablet **b) Horse**

Figure 10. Usual items

The making of the Horse (see photo 19 below) required about 12 kg of resins (PP) and 3 kg of reinforcements (short duramen fibres), i.e. 15 kg of the "PLASTRONIER" to be cast. These two objects, which are useful for childcare centres, required a total of 25 kgs of plastic waste and 6 kgs of reinforcements from the tall-palm tree. For a production of 1000 items, 25 tonnes of plastic waste will have been eliminated from the environment.

Conclusion

The "Plastrônier" composite was implemented by the casting and compression process using the molten plastic waste to make the matrix and the scraps of tall-palm wood, which are the duramen fibers, woven leaves and veins of leaves or twigs. The test specimens extracted from the plate of the "plastronier" composite were subjected to three-point bending on the SCHENKY traction machine in accordance with ASTM-D 790 and the results showed that the "plastronier_rameau" composite withstands bending forces near 350 N but with 3 mm as dimension of deflection, the "Plastronier-nattes" and the "Plastronier-duramen" composites can withstand forces around 150 N with 3 mm as a maximum value of deflection for the "plastronier-nattes", whereas the deflection of the "plastronier-duramen" can be up to 9 mm due to the dispersion of the fibers in the matrix.

The 3 mm of deflection in the case of the "plastronier-nattes", and "plastronier-rameau", is explained by the fact that the matrix-reinforcement interface is not cohesive and as soon as the matrix breaks, there is no longer any question of composite. This composite therefore has mechanical capacities that have made it possible to use it to make decorative objects such as horses and useful objects such as tablets. Producing about 1000 of these objects could lighten the environment by 25 tonnes of plastic waste, especially in countries that do not have advanced technologies for recycling plastic waste.

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