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# Moisture content in PP/OWF composite plates monitored using ultrasound

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## ABSTRACT

This work explores a wood-polymer composite (WPC) made of a polypropylene (PP) polymer combined with olive wood flour (OWF). The longitudinal wave propagation is proposed as an evaluation mean of the WPC viscoelastic properties. Depending on the OWF ratio content, varied from 0 to 30%, the flour dispersion is evaluated in a scanned zone in view to assess the assumption of homogeneity of such WPC plates. In addition, the moisture content can be indirectly highlighted, due to the immersion of the plate in water during its analysis using ultrasound. This effect was measured and evaluated as a function of the immersion time. For those ultrasound measurements, a transducer having a center frequency of 15 MHz and focusing at 54.7 mm in water was used. Indeed, scans were performed over a zone of 100×100 mm<sup>2</sup> and reflection echoes were recorded for each (x, y) position, with a 0.1 mm step. Then, the measurement of the amplitude of the specular echo, combined with the time of flight gives an estimate of the moisture content in the plate. The resulting evaluation of the moisture content is analyzed using a Fick diffusion law. The resolution of the resulting information is also discussed as a function of the transducer properties versus those of the WPC plate.

## 1. INTRODUCTION

The production industry related to olive trees lead to misused products. Thus, the valorization of olive wood flour (OWF) waste envisaged as a reinforcement in polymers, leading to wood-polymer composites (WPC). Natural fibers integrated in a polymer matrix can improve mechanical properties and biodegradability [1] [2] [3]. The polypropylene (PP) was chosen as a matrix for its performance, processing easiness, availability and low cost. The resulting PP/OWF composites constitute the studied family of WPC samples [4]. The resulting mechanical properties are increasing with the OWF mass fraction, in a relative amount. If the load charge exceeds a homogeneous integration and a miscibility limit, the drawbacks are greater than the benefits what is the object of the study of this PP/OWF sample family. Those samples are showing a moisture absorption while immersed in water, due to the micro-porosity of the OWF at the surface. This phenomenon may be the source of mechanical properties degradation in the life-cycle of the WPC.

## 2. WOOD-POLYMER COMPOSITES

### 2.1 WPC samples

The studied WPC samples are those characterized in a previous work [4] in order to deduce their effective acoustical bulk properties. As a result, a set of WPC has been obtained with an increasing charge load, i.e. PP/OWF with a OWF mass loading rate of 0, 10, 20 and 30%. The dimensions of those plates are fixed with a thickness  $d = 4$  mm, a width  $l = 100$  mm and length  $L = 120$  mm, but the analyzed area is reduced to 10×10 mm<sup>2</sup> and centered.

### 2.2 Water uptake

As reported by Bledzki et al. [5] [6], wood-polymer composites (WPC), and particularly thermoplastics reinforced with wood fillers are known as sensitive to the water uptake by the filler, i.e. moisture absorption. In addition, these WPC are characterized by a weak wettability and a poor adhesion between wood-fibers and the thermoplastic matrix. As a result, the tensile strength is not always improved by the wood fillers and the moisture sorption of those composites is high.

Properties such as wettability and hydrophilic nature of the fibers are directly related to the moisture content, as well as the crystallinity or the porosity level of those fibers. Due to this water uptake, it can lead to the degradation of mechanical properties.

Two main mechanisms are involved:

- Water-diffusion through the micro-fissures
- Capillarity transport due to incomplete impregnation

The moisture absorption of WPC samples was highlighted by the works of Bledzki et al. [6] or Lin et al. [7].

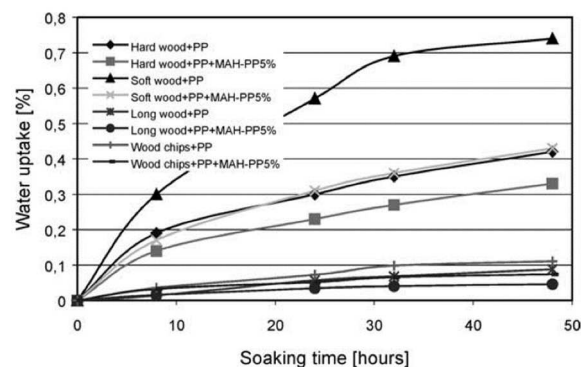


Figure 1. Moisture content of PP/WF50 WPC with and without coupling agent, Bledzki et al. [6].

### 3. DIFFUSION

#### 3.1 Moisture absorption

The most significant parameter for water absorption is the diffusion coefficient [8]. The diffusion equation can be reduced for short times such that  $M(t)/M_\infty \leq 1/2$ :

$$\frac{M(t)}{M_\infty} \approx \frac{4}{d} \sqrt{\frac{D}{\pi}} t \quad (1)$$

where  $M(t)$  is the moisture content at a given time  $t$ ,  $M_\infty$  is the asymptotic value of the moisture content,  $d$  is the thickness of the sample and  $D$  is the diffusion coefficient. Using a two points identification, the diffusion coefficient  $D$  can be evaluated as:

$$D \approx \frac{\pi d^2}{16M_\infty^2} \left( \frac{M(t_2) - M(t_1)}{\sqrt{t_2} - \sqrt{t_1}} \right)^2 \quad (2)$$

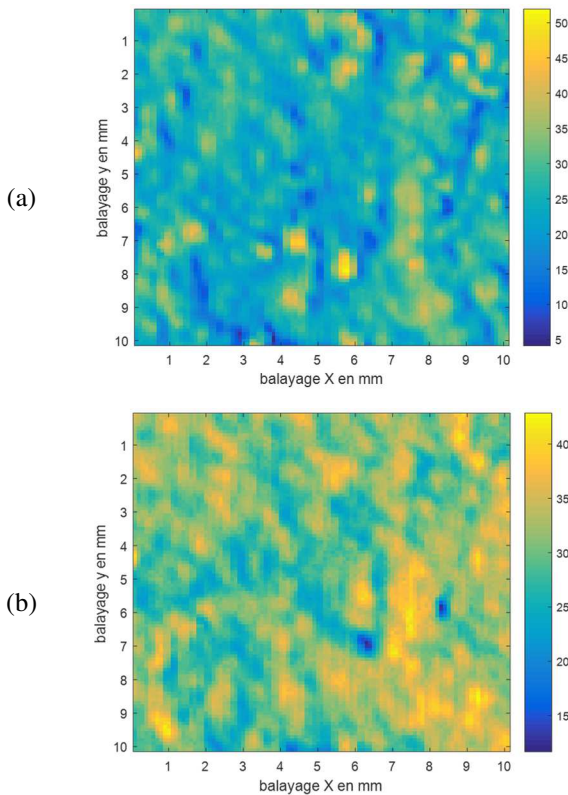
An extent of the diffusion equation involving a power function of time (equation (1)) is a Fick diffusion equation:

$$\frac{M(t)}{M_\infty} \approx K t^n \quad (3)$$

where  $\{K, n\}$  is a set of characteristic constants for the studied sample, with  $n \approx 1/2$  for Fickian diffusion and  $1/2 \leq n \leq 1$  for non-Fickian diffusion.

#### 3.2 Experimental results

The area of analysis was scanned, providing a C-scan map of 101×101 points.



**Figure 2.** C-scans of the specular echoes obtained on the studied area of 10×10 mm<sup>2</sup> of a PP/OWF30 WPC plate: (a) initial C-scan at  $t_0$  and (b) final C-scan at  $t_0 + 48$  h.

### 4. CONCLUSION

In this work, the moisture absorption was evaluated and discussed in comparison with acoustical measurement. The experimental method was consisting in weighting the samples at various soaking times, giving the characteristic asymptotic value of the moisture content and the diffusion coefficient. In comparison, an experimental setup for the ultrasonic characterization of the immersed samples was presented. Some results were shown and discussed. The case of study of a PP/OWF30 WPC illustrates the ultrasound monitoring with the reflectometry method. The values of the surface roughness are also discussed with regard to the acoustical characterization of the surface.

### 5. REFERENCES

- [1] K. Oksman, «Mechanical properties of natural fibre mat reinforced thermoplastic,» *Applied Composite Materials*, vol. 7, pp. 403-414, 2000.
- [2] B. Amar, K. Salem, D. Hocine, I. Chadia et M. J. Juan, «Study and characterization of composites materials based on polypropylene loaded with olive husk flour,» *Journal of Applied Polymer Science*, vol. 122, pp. 1382-1394, 2011.
- [3] K. Qiu et A. N. Netravali, «Fabrication and characterization of biodegradable composites based on microfibrillated cellulose and polyvinyl alcohol,» *Composites Science and Technology*, vol. 72, pp. 1588-1594, 2012.
- [4] N. Bouhamed, S. Souissi, P. Marechal, M. B. Amar, O. Lenoir, R. Leger et A. Bergeret, «Ultrasound evaluation of the mechanical properties as an investigation tool for the wood-polymer composites including olive wood flour,» *Mechanics of Materials*, vol. 148, p. 103445, 2020.
- [5] A. K. Bledzki, V. E. Sperber et O. Faruk, *Natural and wood fibre reinforcement in polymers*, vol. 13, iSmithers Rapra Publishing, 2002.
- [6] A. K. Bledzki et O. Faruk, «Wood fibre reinforced polypropylene composites: effect of fibre geometry and coupling agent on physico-mechanical properties,» *Applied Composite Materials*, vol. 10, pp. 365-379, 2003.
- [7] Q. Lin, X. Zhou et G. Dai, «Effect of hydrothermal environment on moisture absorption and mechanical properties of wood flour-filled polypropylene composites,» *Journal of Applied Polymer Science*, vol. 85, pp. 2824-2832, 2002.
- [8] W. Wang, X. Guo, D. Zhao, L. Liu, R. Zhang and J. Yu, "Water Absorption and Hygrothermal Aging Behavior of Wood-Polypropylene Composites," *Polymers*, vol. 12, p. 782, 2020.