

Hydro-thermoelastic modeling of flax-poly(lactic acid) bio-composites : an inverse method applied to a multi-physics problem

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Companies have to adopt a new economic and environmental development policy in order to anticipate the oil depletion and the limitation of greenhouse gas emissions. In the field of composites, the demand for bio-based materials (biopolymers reinforced by natural fibres) is growing since they can offer equivalent specific mechanical properties compared with traditional composites and better environmental credentials. But in real service conditions, these bio-composites undergo durability issues due to different kinds of damage (hydric, thermal, mechanical and combinations of these loads). The physico-chemical processes taking place in these composites during real aging conditions have been extensively studied in the literature, and lead the deterioration of the material. The complex behavior of each component (fibre and matrix) in relation to these degradations makes the mechanical performance of such composite material very difficult to predict.

The purpose of this paper is to study and model the evolution of the elastic mechanical behavior of bio-based composites used for semi-structural applications, i.e. PLA (poly(lactic acid)) / flax fibre biocomposites (with various short fibre weight contents: 0, 20 and 30%), when immersed in water at different temperatures (20°C, 35°C and 50°C).

The first part of this work consists in studying the influence of hydrothermal aging on the material by measuring its mass uptake and swelling. A pseudo-Fickian 3D diffusion law¹ coupled to an anisotropic swelling behavior² agrees well with experimental data for aging at 20°C, while deviations are observed at 35 and 50°C due to permanent damage induced by water³. These deviations increase with the aging temperature and the fibre content.

Secondly, the dynamic elastic modulus is determined thanks to an unusual, quick and non-destructive method which involves the monitoring of free vibrations of material samples by using a laser sensor and identification through a finite element analysis. Based on a finite element model updating method, the water dependent elastic moduli of each component are identified by minimizing the difference between the simulated homogeneous modulus⁴, which accounts for the water concentration gradient, and the experimental apparent elastic modulus.

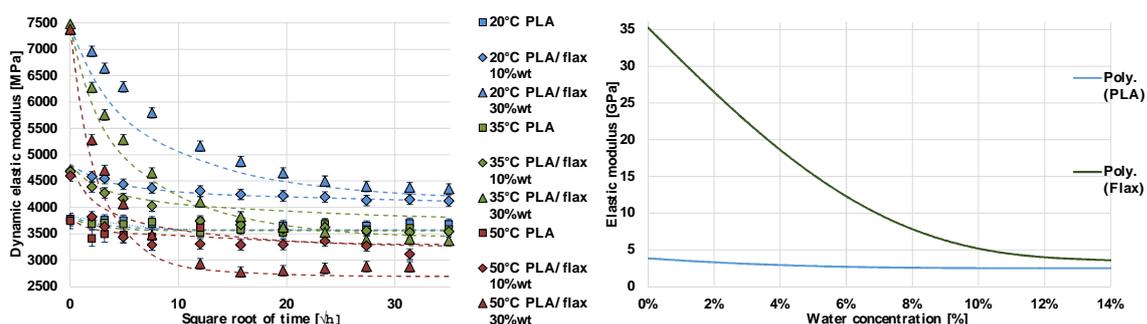


Figure 1: Evolution of the dynamic elastic modulus during aging in water for 3 composites (\square : PLA, \diamond : PLA+10%wt flax, Δ : PLA+30%wt flax) at 20, 35 and 50°C (blue, green and red) (a) and the corresponding optimized evolution of the elastic moduli of matrix and fibres as a function of the water concentration (b).

¹ Carter and Kibler, *J.Compos.Mater.*, **12**, 118, (1978)

² Weitsman, *Fluid Effects in Polymers and Polymeric Composites. Mechanical Engineering Series*, Springer (2012)

³ Azwa and al, *Mater. Design*, **47**, 424, (2013)

⁴ Van Es, *PhD thesis*, Delft Univ.Tech. (2001)