Viscoelastic properties of plant fibers: dynamic analysis and nanoindentation tests.

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It is now established that plant fibers are suitable reinforcements to replace or to complete synthetic fibers for composite applications. They have many well-known advantages such as being renewable, biodegradable and having high specific mechanical properties and intrinsic damping properties that can impart attractive benefits to composite materials. When compared to glass and carbon fibers reinforced polymer composites, PFCs exhibit generally higher damping properties. This is commonly attributed to the polymeric nature of the fibers. It could also result from their hierarchical structure and microstructural specificities. Indeed, damping in composite materials is induced by several microscopic level mechanisms related to the viscoelasticity of both matrix and fibers, but also by the fiber/matrix interface and the friction between fibers inside bundles or between layers. The presence of lumen could also play a role. At this stage, the damping source is not well identified, and the design and the optimization of composites, for structural applications, are then difficult. A better knowledge of the physical phenomena involved is therefore necessary.

A first approach is proposed using dynamic nanoindentation. Different dynamic loading paths are applied to plant fiber composites. Flax fibers are tested *in situ* in the composite. Indents were performed using predefined grids. The sinusoidal signal of force and penetration depth as a function of time are post-processed to ensure a reliable determination of the loss factor. Finally damping maps are plotted. Results allow the variation of elastic and damping properties in the fiber/fiber and fiber/matrix interphases to be quantified and thus to shed new light on the origins of damping in PFCs.

In a second time, a specific experimental set-up is developed based on the analysis of the transverse (bending) vibratory response of a fiber clamped at one end, free at the other one. Both forced (using a piezoelectric actuator) or free (using a release of a static constraint) movements can be generated. The loss factor is then identified from the vibration displacement by tracking the fiber free-end recorded with a high-speed camera. Conclusions are drawn on the damping properties of plant fibers compared to synthetic fibers.

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