Fire the fibre up!
Let's untangle plant fibre's damping behaviour!

Context and objectives

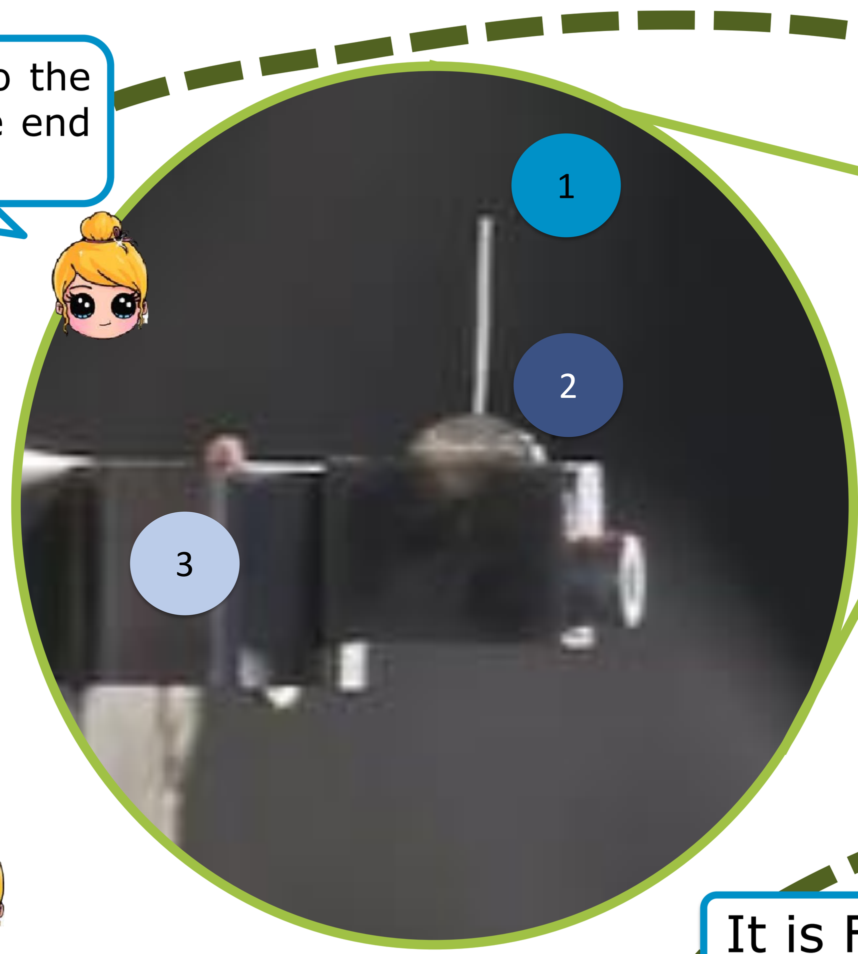
- Environmental concerns regarding synthetic reinforced composites => Find an alternative
- Plant fibre reinforced composite good opportunities [1] => Understanding their properties
- Diverging damping properties in the literature at composite scale => Look at smaller scale… the fibre scale!

Method to determine stiffness and damping based on free vibration tests on a single fibre

The fibre (1) is embedded into the matrix to make it fixed at one end and free at the other

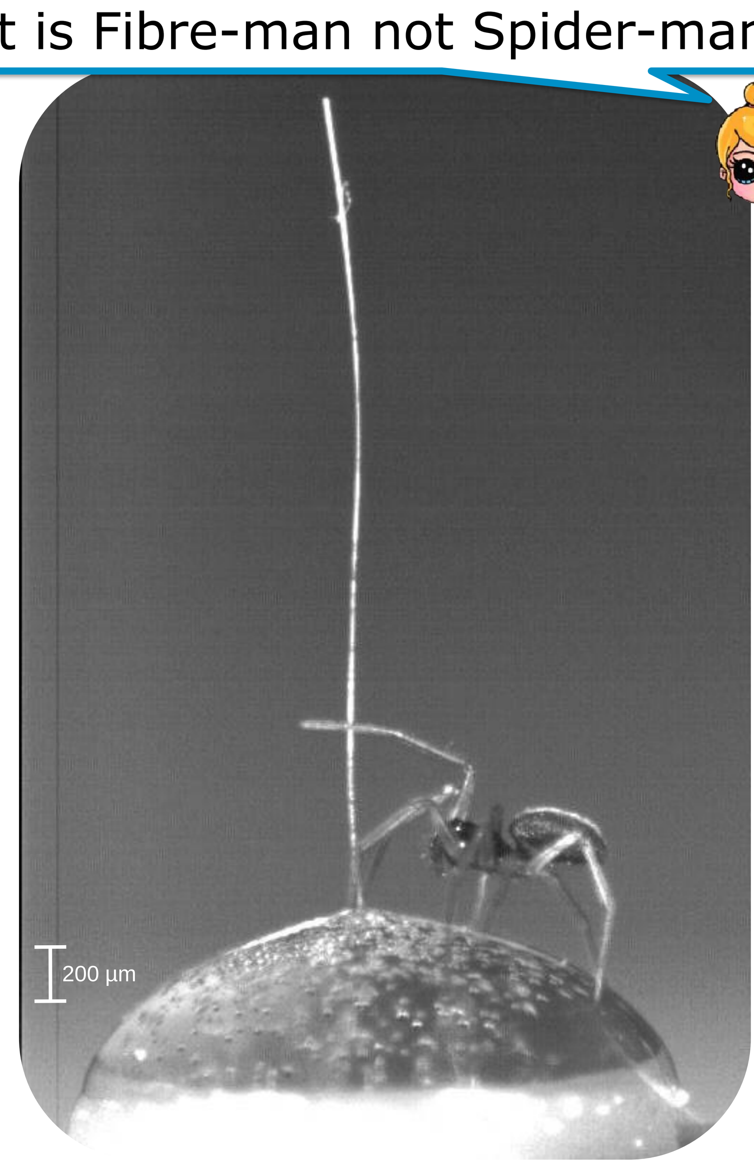
The matrix (2) is designed to limit capilarry effect along the fibre during drying of the resin

The actuator (3) makes the fibre vibrate and the camera captures fibre's induced displacements

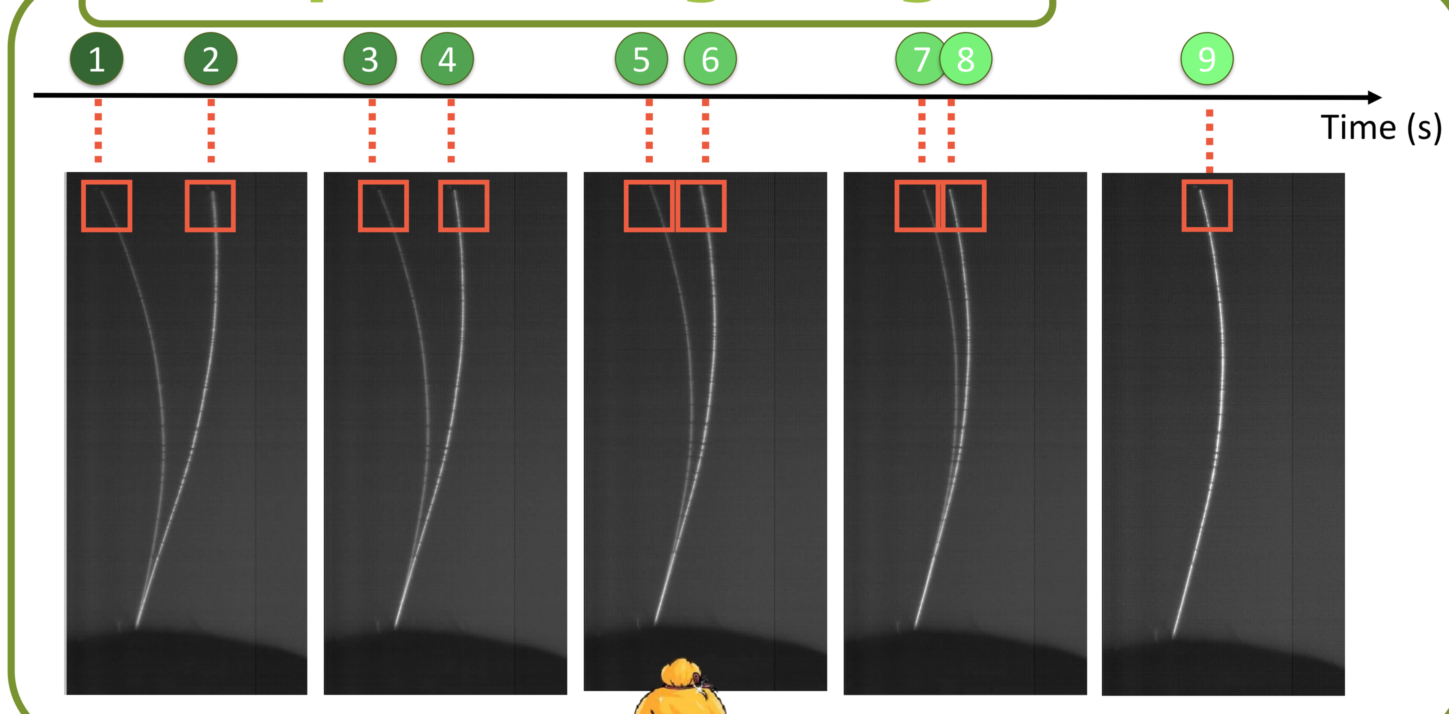


Fast camera (up to 1700 fps) to capture fibre displacements

It is Fibre-man not Spider-man

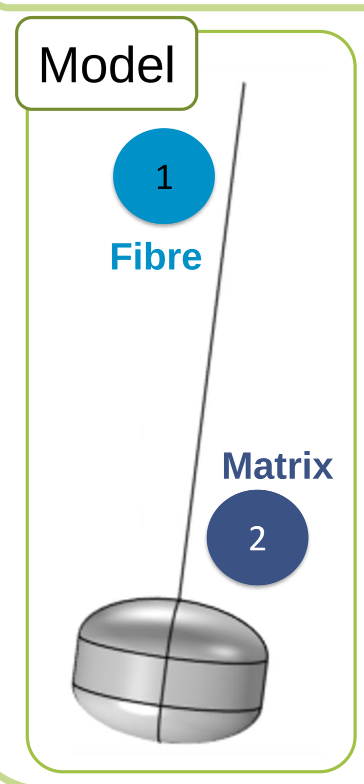


Post-processing images



The amplitude of the displacement decreases with time till the fibre reaches its equilibrium state

Storage modulus identification



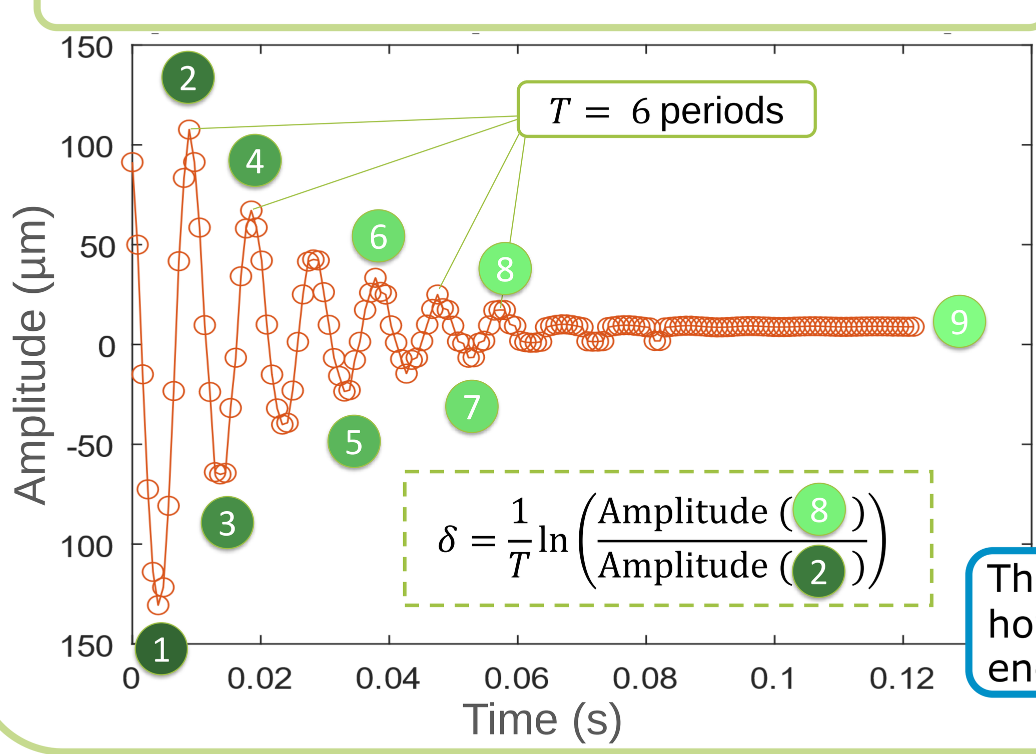
$$E_{fibre} = E_{model} * \left(\frac{f_{fibre}}{f_{model}}\right)^2$$

E_{fibre} is the storage modulus of the real fibre expressed with E_{model} the storage modulus of the model and both frequencies of the model and the real fibre

The model helps to identify fibre's storage modulus with the frequency obtained during the experiment. It represents the stiffness of the material!

Loss factor identification

The loss factor represents the damping capacity of a structure



$$\delta = \frac{1}{T}\ln\left(\frac{\text{Amplitude (8)}}{\text{Amplitude (2)}}\right)$$

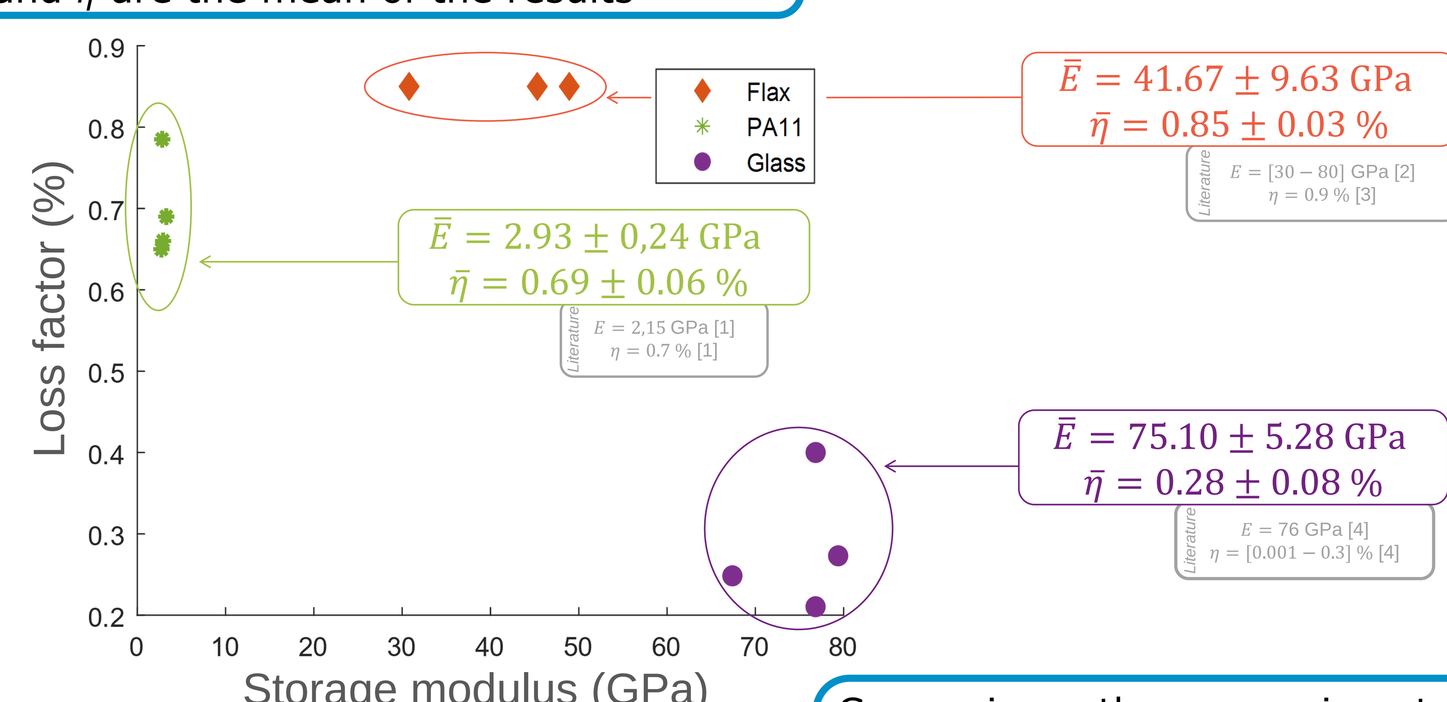
$$\eta = \frac{2}{\sqrt{1 + 4\frac{\pi^2}{\delta^2}}}$$

η is the loss factor expressed with δ the logarithm decrement

The shape of the curve describes how the structure is dissipating energy => how it is damped!

Results

Tests have been performed on 4 fibres of each types (flax, PA11 and glass), the values of E and η are the mean of the results



Flax: $\bar{E} = 41.67 \pm 9.63$ GPa, $\bar{\eta} = 0.85 \pm 0.03$ % — Literature: $E = [30 - 80]$ GPa [2], $\eta = 0.9$ % [3]

PA11: $\bar{E} = 2.93 \pm 0{,}24$ GPa, $\bar{\eta} = 0.69 \pm 0.06$ % — Literature: $E = 2{,}15$ GPa [1], $\eta = 0.7$ % [1]

Glass: $\bar{E} = 75.10 \pm 5.28$ GPa, $\bar{\eta} = 0.28 \pm 0.08$ % — Literature: $E = 76$ GPa [4], $\eta = [0.001 - 0.3]$ % [4]

Comparing the experimentally obtained values and the values that the literature gives, is a good way to validate the protocole

Conclusions & perspectives

- Stiffness and damping identification methods => Experimental protocol consistant with litterature
- Four fibres of each type tested => Interest of having more data for robustness => Generalise to multiple types of fibres
- Limits of the experiments identified (surrounding conditions) => Develop an isolated and thermally regulated chamber
- Damping properties identified at fibre scale => Look at larger scale … the fibre/matrix interphase scale!

[1] Mazan, T., Berggren, R., Jørgensen, J. K., & Echtermeyer, A. (2015). Aging of polyamide 11. Part 1: Evaluating degradation by thermal, mechanical, and viscometric analysis. *Journal of Applied Polymer Science*, *132*(20).
[2] Charlet, K. (2008). *Contribution à l'étude de composites unidirectionnels renforcés par des fibres de lin: relation entre la microstructure de la fibre et ses propriétés mécaniques* (Doctoral dissertation, Université de Caen/Basse-Normandie).
[3] Davies, G. C., & Bruce, D. M. (1998). Effect of environmental relative humidity and damage on the tensile properties of flax and nettle fibers. *Textile Research Journal*, *68*(9), 623-629.
[4] Lenk, P., & Coult, G. (2010). Damping of glass structures and components. In *Challenging Glass Conference Proceedings* (Vol. 2, pp. 341-350).

Contacts
Fanny PELISSON
Pauline BUTAUD, Vincent PLACET, Morvan OUISSE
Besançon, Belfort, Montbéliard, Sévenans
www.femto-st.fr

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