

Revealing Single Fibre Damping with Advanced Multimodal Testing

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ABSTRACT

Fibres are widely used across industries, including textile, paper, packaging, composites and medical applications. Improving their performance requires a deeper understanding of their mechanical behaviour. Due to their micrometric diameter, accurately measuring their dynamic behaviour remains a significant challenge. The limited availability of data on key properties, such as damping, hinders further advancements in the field. This article explores methods for characterizing the dynamic behaviour of elementary fibres: vibration testing, dynamic nanoindentation, dynamic mechanical analysis and micro-Brillouin light spectroscopy. These techniques determine the loss factor of four fibre types: glass, PA11, silk and flax. Results show that for the same fibre type, damping values vary depending on the technique. For instance, for glass fibre, the loss factor measured by vibration tests under vacuum ranges between 0.2 and 0.3%, whereas it is identified at 3% using dynamic nanoindentation and between 2 and 3% with Brillouin spectroscopy. In all cases, the damping of studied organic fibres, whether synthetic or natural, is significantly higher than that of inorganic glass fibre.

INTRODUCTION

The use of natural fibres dates back over 30,000 years, with applications in textiles, construction, and, more recently, in various industrial uses [1]. Historical evidence shows that fibres such as flax were used for clothing and incorporated into composite materials such as bricks and reinforced pottery. In the 20th century, inorganic fibres such as glass, carbon and synthetic fibres such as Kevlar revolutionized composite materials thanks to their excellent mechanical properties [2]. However, their production is energy-intensive and results in a substantial environmental impact. In contrast, natural fibres are experiencing renewed interest due to their environmental benefits and their potential as reinforcements for composites, offering a good alternative to synthetic fibres such as glass. Among their attractive properties, natural fibres exhibit interesting damping capabilities, which play a crucial role in applications requiring vibration and noise reduction. Damping, which refers to the ability of materials to dissipate mechanical energy, is a key parameter in applications ranging from automotive and construction composites to ballistic materials. Understanding and quantifying damping not only allows for better design of high-performance composites but also enables the optimization of materials for specific uses. Determining damping at the scale of elementary fibres remains a complex challenge, as, to the best of our knowledge, no values are currently available in the literature for glass fibres, and only limited studies have addressed natural fibres. This article presents a comparative study of four distinct methods for measuring the damping of elementary fibres: vibration-based method, dynamic nanoindentation, dynamic mechanical analysis (DMA), and micro-Brillouin light spectroscopy. These techniques are applied to a range of fibres (glass, PA11, silk, and flax) to investigate variations in damping based on fibre types. By combining these techniques, the study

compares various excitation types and frequencies, boundary conditions, and measurement scales, offering a deeper understanding of fibre damping behaviour, and, in some cases, providing the first-ever damping values at the fibre scale.

RESULTS & CONCLUSIONS

The results presented during the conference will focus on the four types of fibres and the four experimental techniques used. Micro-Brillouin light spectroscopy is a non-contact technique involving high-frequency excitation. It was employed to evaluate both longitudinal and transverse fibre damping. Grid dynamic nanoindentation, a contact-based method, was used to measure the damping within the fibre's cross-section and at the fibre/matrix interface. Dynamic mechanical analysis, another contact-based low-frequency method, further characterised fibre damping under tensile loading and controlled environmental conditions, offering a complementary perspective. Finally, the vibration testing (with a fixed-free sample) method combined with image tracking, a non-contact low-frequency approach, enabled the characterisation of damping along the fibre length while also assessing the effects of environmental factors such as pressure and temperature.

Among the key findings, glass fibres consistently exhibit the lowest damping values across all methods. Brillouin spectroscopy reveals that PA11 has the highest loss factor (10.4%), followed by silk (10.3%) and flax (8.3%), while glass fibres have the lowest one at 2.3%. Additionally, the effect of air pressure on damping was characterized for each fibre using vibration method under controlled vacuum conditions. At atmospheric pressure, all samples exhibit an apparent loss factor around 20%. However, under vacuum, where aerodynamic effects are negligible, glass fibres show a loss factor of 0.2–0.3%, while flax fibres exhibit values ranging from 1.5 to 2.1%. Further insights into these results and their implications for material design will be explored during the conference.

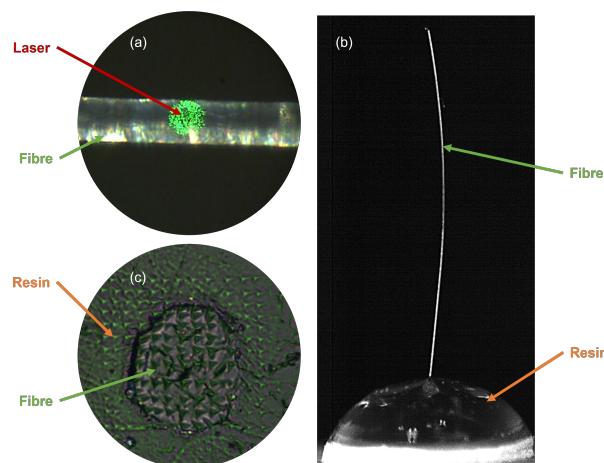


Fig.1 (a) flax fibre under laser Brillouin spectroscopy, (b) PA11 fibre sample prepared for vibration testing, and (c) flax fibre embedded in GreenPoxy after nanoindentation mapping

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REFERENCES

- [1] Eliso Kvavadze et al. 30,000-Year-Old Wild Flax Fibers. *Science* (2009)
- [2] Nagavally, R. R. (2017). Composite materials-history, types, fabrication techniques, advantages, and applications. *Int. J. Mech. Prod. Eng.*, 5(9), 82-87.