Improving the morphometric measurement of natural fibres cross-section to assess their mechanical properties

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ABSTRACT

Dimensional characteristics of natural fibres are highly dependent on their botanical origin and extraction processes. Furthermore, their dimensions and physical properties could vary according to environmental conditions (humidity, temperature...). Advances in the development of natural fibres reinforced composites for engineering applications require a reliable prediction of their mechanical performances. From this point of view, the morphology of natural fibres should be assessed accurately so as to implement their intrinsic mechanical properties in mechanical predictive models. The dimensional measurement of natural fibres cross-section is usually based on assumptions of their sectional shape and rarely takes into account dimensional variations along their length. This study proposes a detailed dimensional analysis of various natural fibres species based on the comparison of two very different approaches: microscopic observations and an automated laser scanning technique.

INTRODUCTION

Currently, the industry is showing a growing interest in the development of biocomposites. Natural fibres of various botanic origins are used as reinforcement in polymer composites (Mohanty et al., 2005) as a solution to current environmental issues, such as the reduction of greenhouse gas emissions and pollution through the use of renewable and biodegradable resources and lightweight materials. However, natural fibres lack a scientific and technological history enough to claim a controlled and constant level of performances, and both agricultural and industrial sectors are investigating potential solutions. In order to be able to accurately model and predict the mechanical behavior of biocomposites from their manufacturing processes to their service use, it is essential to have a thorough knowledge of the morphological and mechanical properties of natural fibres and their evolution in specific environmental conditions. Indeed, natural fibres, whatever their origin and the scale considered can show wide variations in their dimensional features. Müssig and Stevens (2010) investigated the evolution of the length, the width and the cross-sectional area (CSA) of several species of natural fibres. They observed a strong contrast of morphological dispersion between elementary fibres and fibre bundles. Several measurement methods have been used to assess the dimensions of natural fibres. However, they often rely on simplified assumptions of their shape that may be valid for synthetic fibres but not for the specific shape and dimensional irregularities of natural fibres (Müssig and Stevens, 2010). The determination of the mechanical properties of fibres are determined from the dimensional data collected with these methods (Haag and Müssig, 2016), which partly explains the large scattering of fibre mechanical properties reported in literature. The purpose of this study is to better assess the dimensions of natural fibres by considering their botanical origin and morphological features.

RESULTS AND CONCLUSIONS

Two methods of morphometric measurement were used and compared. The first method was proposed by Müssig and Stevens (2010) and Thomason and Carruthers (2012). It consists in embedding fibres in an epoxy resin pad which undergoes successive polishing so as to observe and measure their actual cross-sectional dimensions using an optical microscope. The second method uses an automated laser scanning device (FDAS), developed by Diastron Ltd (Andover, UK), to measure the transverse dimensions of fibres along their length on 360 degrees. Data collected by the FDAS device were correlated with those obtained by optical microscopy for five species of natural fibres (hemp, flax, sisal, palm and nettle). It was found that correction factors should be applied. These factors are associated to the morphometric characterics of natural fibres related to their botanical origin. As an example, Fig.1 shows a correlation between the two methods.

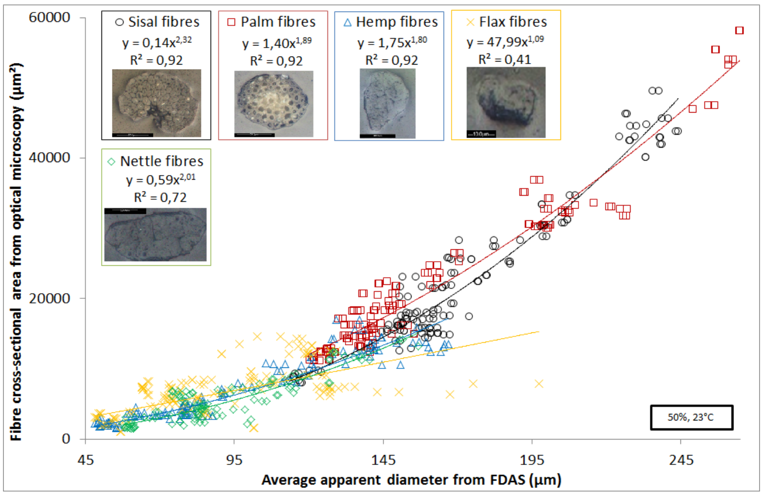

Fig.1: Correlation between average apparent diameter from the FDAS and cross-sectional area from the optical microscopy.

The large number of data collected with the laser scanning technique makes an interesting experimental basis. Take account of morphological irregularities to improve the calculation of mechanical properties compared to the methods commonly used. It allows envisaging the evaluation of the tensile mechanical properties of the fibres based on a 3D parametric model implemented in a finite element simulation of a tensile test.

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