TOWARDS 3D DIGITAL IMAGE CORRELATION OF IN SITU TESTED SINGLE FLAX FIBRES USING OPTICAL PROJECTION TOMOGRAPHY

Anouk Chevallier[1(*)], Markus Kakkonen[2], Olli Tanhuanpää[2], Florian Boutenel[1], Violaine Guicheret-Retel[1], Cédric Clévy[1], Pasi Kallio[3], and Vincent Placet[1]
[1] Université Marie et Louis Pasteur, SUPMICROTECH, CNRS, Institut FEMTO-ST, F-25000 Besançon, France
[2] Fibrobotics Oy, Korkeakoulunkatu 1, 33720, Tampere, Finland
[3] Faculty of Medicine and Health Technology, Tampere University, Finland
[(*)] Email: anouk.chevallier@femto-st.fr

ABSTRACT

The intricate morphology of plant fibres makes it challenging to accurately determine their elastic properties. This study explores the effectiveness of in situ optical projection tomography on single fibres for this purpose. The results demonstrate that this non-destructive and non-invasive technique enables the precise reconstruction of the external envelope of plant fibres during a tensile test, with a voxel size of the order of 0.244 µm. This opens promising opportunities for identifying the elastic and hygro-elastic properties of plant fibres.

INTRODUCTION

Plant fibres exhibit complex morphology and spatial heterogeneity in their microstructure and biochemical composition [1]. For this reason, the questions of the heterogeneity of the deformation fields in these fibres subjected to mechanical loading and its effect on the determination of elastic properties remain open in the literature [2]. Measuring strain fields using image correlation is challenging, notably because of the micrometric size, high length/diameter ratio of plant fibres and the shallow depth of field of commercially available lenses.

This study aims to evaluate the performance of volumetric digital image correlation using projections acquired through Optical Projection Tomography (OPT). This technique, developed by Tampere University and by Fibrobotics, enables the object to be reconstructed in 3D from photographs taken at different roll angles of a fibre and using a tailored reconstruction algorithm. To this aim, a series of in situ tensile tests on flax fibres was conducted under OPT using an experimental setup comprising two actuators positioned at the fibre's extremities. This enabled the fibre to be photographed, in our case every 0.4° between 0° and 180°. A linear actuator translated one end of the fibre, along with the attached rotary actuator, to apply the mechanical load. The tensile force is measured using a sensor placed between the second rotary actuator and the framework of the experimental device.

A series of tomography scans at different loading levels are carried out on the same fibre. The first scan is performed when the fibre is subjected to the pre-load tension, which allows its longitudinal axis to be the axis of rotation of the actuators. Subsequent scans are performed at pre-load+47 mN and pre-load+62 mN. Finally, a tomography was carried out at pre-load+94 mN.

RESULTS AND CONCLUSIONS

OPT demonstrated its ability to reconstruct the external contours of elementary flax fibres in 3D with reduced acquisition time compared with X-ray tomography, e.g. 7 minutes for OPT vs 30 minutes for X-ray tomography for a 500 µm long fibre, taking an equivalent number of projections per rotation [3]. The reconstruction times are equivalent for both techniques. In addition, the resolution of the reconstructed fibre is 0.244 µm/voxel, compared with 0.430 µm/voxel for X-ray tomography performed with an EasyTom tomograph (RX Solutions, Chavanod, France) with the X-ray source Hamamatsu Open Type Microfocus L10711.

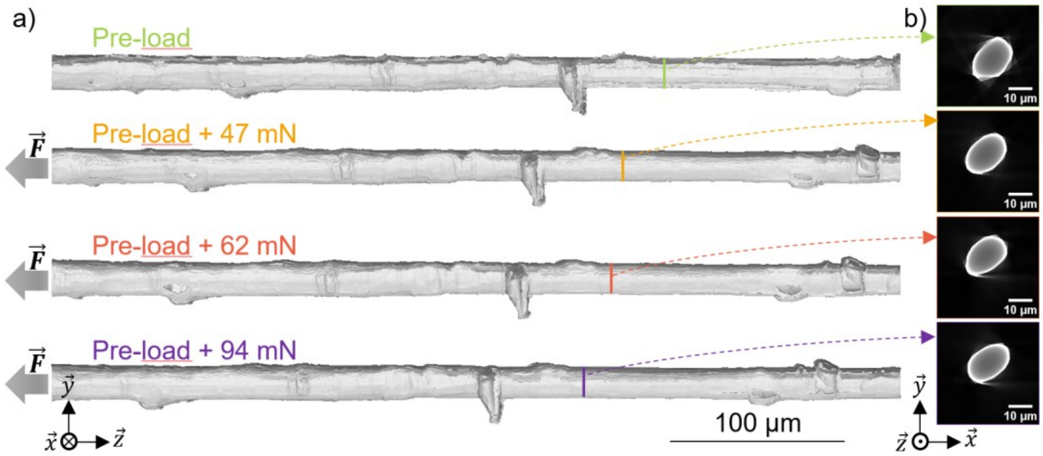

Fig.1 Reconstruction of the same flax fibre from projections obtained by OPT at different tensile loading levels (a) longitudinal view (b) example of the same cross-section at different at those different loading level

This technique makes it possible to track defects on the surface of the fibre during the tensile test (Figure 1 a). The hypothesis of homogeneous longitudinal deformations in the fibre during the test can thus be investigated. The measurements of the longitudinal deformation field as well as those of the same cross-section reconstructed at different loading levels (Figure 1 b) could lead to an evaluation of the Poisson's ratio. The heterogeneity of strains in zones close to defects could also be investigated.

Further developments in the analysis of the measurements are still required before this new technique can be fully exploited.

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