WICKING IN YARN WITH FAST SYNCHROTON X-RAY TOMOGRAPHY

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Summary: Water uptake in yarns of different configurations and fiber materials is imaged at very low acquisition time and phase-contrast enhancement with fast synchroton X-ray computer tomography.

1. INTRODUCTION

Textiles are made of woven or knitted yarns, which are bundles of fibers twisted or spun together. The number of fibers in one yarn can vary from a few to hundreds, and can be made of natural materials (cotton, wool) or synthetic materials (polymers such as polyester or acrylic). When these fibers are wettable, a liquid, here water, can be uptaken due to capillary forces and dependent on surface properties. This spontaneous imbibition in textiles is called wicking, and we use the same word here for liquid uptake in yarns. With the low acquisition time and phase-contrast enhancement of fast synchroton X-ray tomography, it is possible to image water wicking in a yarn. We present here the application of this technique to wicking in yarns and provide the first full 3D time-resolved documentation of liquid and fiber geometry during wicking.

2. EXPERIMENTAL METHOD

The experiment was performed at the TOMCAT beamline of the Swiss Light Source (SLS) of the Paul Scherrer Institute (PSI) in Villigen, Switzerland. The yarns used include yarns of polyethylene terephthalate (PET), polyamide (PA), polypropylene (PP) and cotton at different twisting levels. For imaging, the yarn is fixed inside a sample holder as shown in Figures 1a and b. The sample holder allows to maintain the tension applied to the yarn. The base of the sample holder is a water recipient. Image acquisition is done as follows: first the dry yarn is imaged, then water is introduced in the base of the sample holder, this is followed by continuous projection acquisition of one full tomogram every 0.6 second during water uptake.
Analysis is performed in terms of moisture content versus height as function of time and water configuration within the pore system. After reconstruction, the 8-bit 3D images are segmented to separate water and fibers. The full procedure consists in segmenting the fibers and water from the air, removing background effects and subtracting the initial dry image from all subsequent image, thanks to the quasi absence of displacement of the fibers in the yarn, to obtain the water alone in time series.

3. RESULTS

We present the results on the uptake experiments, showing here the results for a polyester yarn. The profiles in Fig. 1c are given in terms of number of pixels of water per slice versus height over the uptake experiment. The amount of water varies greatly with height, indicating variations in porosity, and with time, indicating strong steps in moisture content. Highlighting the cross sections at two heights, Fig. 1 (d) shows the low porosity at 2.05 mm height in contrast to the much more porous system found at height 2.6 mm. Fig. 1e shows the cumulative moisture

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content within the two slices versus time, where the filling of three pores correspond to the three major steps on the green curve. The blue curve shows the regular filling in the lower slice.
In this work, the yarn and water geometries as well as their evolution in time are documented at high spatial and time resolution, allowing the process of water wicking in yarns to be better understood.

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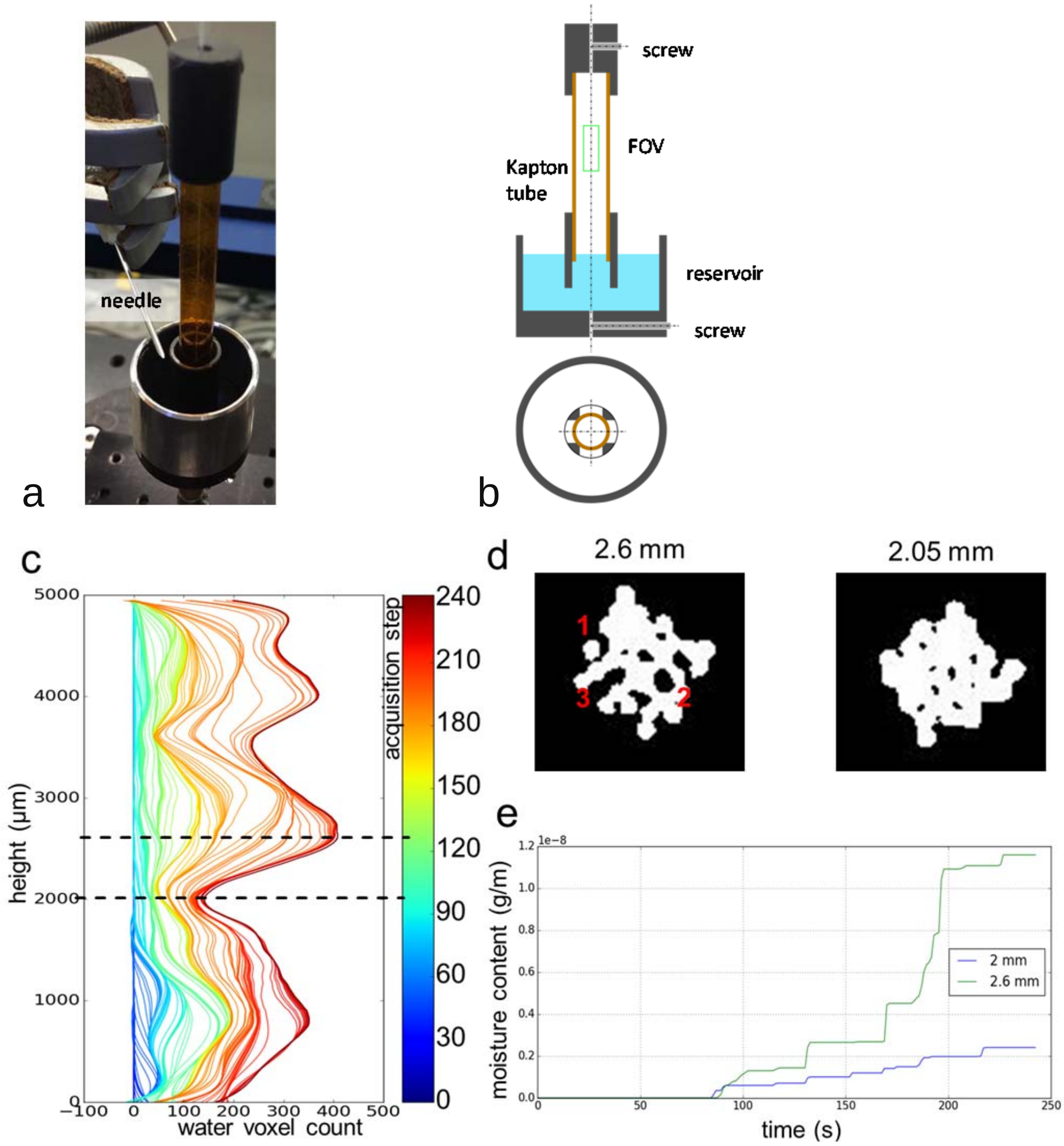

Figure 1: (a) Photo of the sample holder on the stage at Tomcat, (b) schematic representation of the sample holder showing the system to hold in place the yarn and the path of water uptake, (c) number of pixels of water per slice versus height, over 2minutes, (d) two examples of the horizontal slice in the yarn as indicated in (c) with dash lines. (e) cumulative moisture content within the two slices shown in (d) versus time, where the filling of three pores correspond to the three major steps on the green curve.