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Time and spatial resolved X-ray imaging of wicking in interlaced yarns

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Understanding wicking dynamics in textiles is challenging due to the complex pore structure of yarns as well as of the interfaces between interlaced yarns. Time-resolved synchrotron X-ray tomographic microscopy (XTM) is performed at the TOMCAT beamline of the Swiss Light Source of Paul Scherrer Institute in Switzerland. Full high-quality tomographic scans of 5.5 mm height with voxel size 2.75 μm are performed at 2.5 Hz.

XTM reveals the pore structure of the yarns and the interface zone at the yarn contact. In addition, the evolution of the water configuration is documented with high temporal and spatial accuracy. Segmentation of the pore space shows that yarns contain long elongated pores connected laterally with a small number of throats, while the pore space at the interface zone shows a saddle shaped waffle structure originating of the contact of two orthogonally stacked yarns consisting of parallel fibers. Free energy analysis shows that such a pore structure does not enhance flow due to the occurrence of minima in capillary pressure.

Analysis of the XTM data shows an irregular wicking process characterized by two distinct periods: fast pore filling events followed by long time delays between different pore-to-pore transitions [1]. As a result, the wicking process does not follow classical square root of time behavior as predicted by Washburn equation. For the interlaced yarns, we observe that some samples even show very much longer time delays during flow through the interfaces at yarn-to-yarn contacts, while other do not show delays. Therefore, we determine the free energy evolution, determined from the change in interface areas, both water-air area and water-fiber area, as obtained from the images at each time step. The capillary pressure is obtained as the partial derivative of free energy to the water filled pore volume, also determined from the images. We find that wicking is delayed at the pore-to-pore and yarn-to-yarn transitions when experiencing a minimum in capillary pressure. The occurrence of a minimum in capillary pressure is explained by the particular pore structure at the contacts. We also determine the resistance from the volume flux and capillary pressure assuming Darcy's law, finding that no extra resistance exists at the contacts. Excluding extra flow resistance as origin for the delays at the contacts makes us conclude that the delays are originating from the occurrence of minima in capillary pressure due to particular pore structure arrangements at the contacts.

As a consequence, heterogeneity in fiber arrangements at the contacts may prevent the occurrence of minima in capillary pressure and delays, as observed for some samples. As a practical implication for the development of wicking enhancing fabrics, irregular pore structures should be preferred and yarns with equally sized circular filaments, as used in the present study, be avoided.

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References

[1] R. Fischer et al, 10.1103/PhysRevE.103.053101

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

In person

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