Contribution ID: **560** Type: **Oral 20 Minutes**

Understanding Wicking in Textile by Multiscale Imaging and Modeling

Thursday, 17 May 2018 11:05 (15 minutes)

Textiles are porous media found in a wide variety of configurations, resulting from weaving, knitting or crocheting yarns into networks. Textiles consist of multiple scales of fiber, yarn, fabric and multilayered systems, each showing their own porosity system and complexity. Wicking, or the spontaneous liquid capillary uptake in the resulting multiscale pore system, needs a multiscale approach. We present a multiscale framework to predict the wicking behavior incorporating pore network modeling and continuum transport modeling approaches, using high-resolution lab X-ray tomography for identifying the pore configurations. For validation, we use synchrotron X-ray fast-tomography of water uptake at yarn scale and neutron projection at textile scale.
At yarn scale, we first obtain the yarn configuration by highly resolved submicron X-Ray computed tomography. Then, we extract, from this geometry, the information required to develop a pore network capturing all the appropriate complexity, namely long undulating pores, with a loose system of throats and contacts. The configuration of yarns is particularly challenging when analyzed towards building a pore network. Then we develop a pore network model that allows simulating capillary uptake in the yarn system. Given the long aspect ratio of these pores, we track the developing of liquid film building up along the yarn and filling up of the yarn pore space.
We then isolate a representative element of the textile. Knowing the intra-yarn structure and transport properties, we examine the inter-yarn wicking properties by imaging fabric structures at lower spatial resolution of several microns but larger field of view. A mesoscale pore network is constructed on top of the microscale yarn pore network. This modeling approach gives us the three-dimensional permeability tensor of a given fabric element, i.e. a certain knitting stitch or woven pattern.
Fabrics are repetitive patterns of such structural elements. We use the derived mesoscale transport properties to model the water transport on fabric scale. A Darcy's type continuum approach allows us to predict the wicking behavior of different fabric patterns, also considering gravity. Previous neutron projection experiments and finite-element modeling studies showed good agreement of the multi-porous modelling with the observed wicking behavior (Parada et al. 2017a,b).
Understanding the capillary uptake and redistribution of liquid water in textile not only can improve comfort in clothing but also protect firefighters under extreme conditions or find application in medicine.

References

1. Parada M, Vontobel P, Rossi RM, Derome D, Carmeliet J. (2017a) Dynamic wicking process in textiles, Transport in Porous Media, 119:611–632.
2. Parada M, Zhou X, Derome D, Rossi RM, Carmeliet J. (2017b) Modelling wicking in textiles using dual porosity approach, accepted for publication in Textile Research Journal.

References

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Session Classification: Parallel 10-G

Track Classification: GS 2: Computational challenges in porous media simulation