Coupled heat and mass transfer in wood and wood-based products: macroscopic formulation, upscaling and multiscale modelling

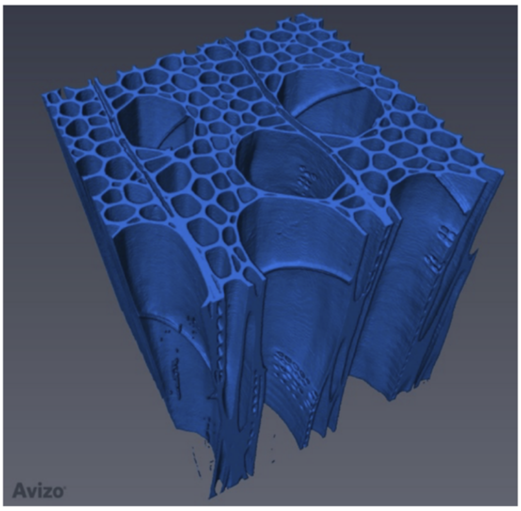
Patrick Perré[a,b]

[a]LGPM, CentraleSupélec, Université Paris-Saclay, 8-10 rue Joliot-Curie, 91 190 Gif-sur-Yvette, France
[b]LGPM, CentraleSupélec, CEBB, 3 rue des Rouges Terres, 51 110 Pomacle, France
patrick.perre@centralesupelec.fr

This conference is devoted to multiscale approaches of coupled transfer in lignocellulosic products, with particular attention to configurations leading to the failure of local thermodynamic equilibrium.

The macroscopic formulation of coupled heat and mass transfer in porous media will be presented first. Upscaling methods, such as homogenization or volume averaging, allowed a well-established set of macroscopic equations to be obtained [1]. This classical formulation of coupled heat and mass transfer in porous media assumes what is called the local thermodynamic equilibrium. This ensures important facts at the microscopic level such as a unique and uniform temperature for all phases of the porous medium or the equilibrium between the partial pressure of water and the bound water. Some simulations will be presented to highlight the importance of the anisotropy of wood or the strong heat and mass transfer coupling arising in Low Density Fibreboard.

This macroscopic formulation needs to be supplied by relevant effective parameters. Nowadays, thanks to the spectacular progresses in 3D imaging and High Performance Computing, these effective parameters can be predicted by 3D calculations on real pore morphologies. Recent examples will be presented for transfer properties of wood and bio-based building materials [2].



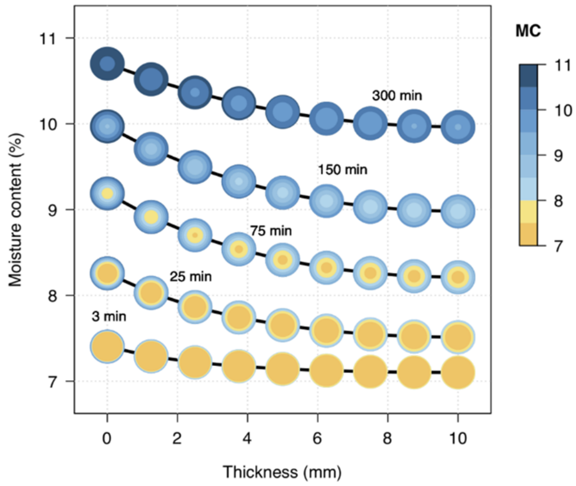


Figure 1: Nano-tomographic scan of poplar (left) and dual-scale modelling of sorption (right)

The remaining part of the conference will be devoted to configurations generating the absence of local thermodynamic equilibrium. Such situations, arising more often than expected, require a comprehensive multiscale approach. In one way or another, the local history of the product must be embedded in the formulation. Two approaches will be discussed here:

- the concept of distributed micromodels, with various assumptions regarding the coupling between scales[3,4],
- the transfer of all the information at the macroscopic level, in which the concept of internal variables allows the history of the microscopic field to be efficiently considered [5].

References

[1] S. Whitaker. Coupled transport in multiphase systems: a theory of drying, Advances in Heat Transfer, volume 31, pages 1–104, Elsevier, 1998.
[2] M. Louërat, M. Ayouz, P. Perré. Heat and moisture diffusion in spruce and wood panels computed from 3-D morphologies using the Lattice Boltzmann method, J. Thermal Sci., 130: 471-483, 2018.
[3] E. Showalter. Distributed microstructured models of porous media. Int. Series of Numerical Mathematics, 114:155–163, 1993.
[4] P. Perré. Multiscale modelling of drying as a powerful extension of the macroscopic approach: application to solid wood and biomass processing. Drying Technol., 28: 944–959, 2010.
[5] P. Perré. Coupled heat and mass transfer in biosourced porous media without local equilibrium: a macroscopic formulation tailored to computational simulation, Int. J. Heat Mass Transfer, under review, 2019.

ISBN: 978-91-88898-64-7