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Analysis of capillary pumping during the drying of heterogeneous porous media using Lattice Boltzmann modelling

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The drying of heterogeneous porous materials is accompanied by capillary pumping from large to small pores which results in the surface remaining partly wet, guaranteeing an almost constant drying rate. At certain degree of saturation, the capillary pumping is turned off and the material experiences a decreasing drying rate. A two-component two-phase Lattice Boltzmann model [1] is used at pore scale to simulate the convective drying process of a dual porosity layered porous material showing the influence of inflow air speed (Re number), inflow vapor concentration difference from the liquid-vapor interface and contact angle. Using these parameters, a universal scaling law is derived which allows predicting the drying rate during the constant drying period [2].

The conditions for capillary pumping are derived based on simulation of the drying of a system of two (and four) connected channels of different size. Sequential drying of the channels from large to small guarantees a maximal drying rate, and is controlled by the capillary pressure difference between the channels and the fluid permeability of the connecting pores. An analytical model at pore scale is developed based on this interaction between capillary channels where the drying across the boundary layer is modelled with a mass transfer coefficient. This analytical model is applied to the drying of real porous materials, like ceramic brick and calcium silicate stone. The former material shows from start a high drying rate and dries out over several days, while the second material needs hundreds of days to dry. Using the developed drying model and a known pore size distribution, the drying curve for these two materials can be predicted with good agreement. Finally, we use this new model as a toy model to design the pore structure of materials to meet expected drying patterns, showing that the presence of well-connected coarse pores of different sizes promotes a fast drying of porous materials.

Participation

In-Person

References

[1] Linlin Fei, Feifei Qin, Jianlin Zhao, Dominique Derome and Jan Carmeliet, Pore-Scale Study on Convective Drying of Porous Media, Langmuir, vol. 38: no. 19, pp. 6023-6035, Washington, DC: American Chemical Society, 2022. DOI: 10.1021/acs.langmuir.2c00267

[2] Linlin Fei, Feifei Qin, Jianlin Zhao, Dominique Derome, Jan Carmeliet, "Lattice Boltzmann modeling of isothermal two-component evaporation in porous media". Journal of Fluids Mechanics, Accepted, (2022).

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