Thin porous media: identification of specific properties and definition from a case study

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We study numerically the process of quasi-static invasion of a fluid in thin porous layers from multiple inlet injection sources. This example clearly indicates that thin porous media can be considered as a distinct class of porous media. Our study also suggests that the fact that the transport properties depend on the thickness, thus are scale dependent, can be considered as a generic characteristic of thin systems. This will be well illustrated through the specific process considered. In this example, the behaviour of sufficiently thin porous media is distinct from that of thicker porous media. For example, the average number of breakthrough points varies as a function of the system thickness when the porous layer is sufficiently thin. By contrast this number becomes independent of the system thickness when the system is sufficiently thick. Our results also reveal that the behaviour of ultrathin systems is different from thicker thin systems. The number of breakthrough points varies according to a power law in a sufficiently thick, not too hydrophilic thin system whereas the variation is different for an ultrathin porous medium, slower than the power law scaling, and not described by a power law behaviour.

The fact that the properties are scale dependent in a thin system is also well illustrated through the study of the defending phase transport properties. Contrary to what was generally assumed in many previous works, there is not a one-to-one relationship between the overall diffusive conductance and the mean saturation in a thin system. The diffusive conductance depends not only on the liquid saturation but also on the system thickness. These findings will be discussed in relation with the so-called water management problem in proton exchange membrane fuel cells (PEMFCs), e.g. [3],[5], [6], an object of great technological importance formed by several thin porous layers.

Our study also indicates that pore network (PN) simulations are well adapted to the study of two-phase flow in thin porous media. They lead to physically better results than the classical continuum approach owing to the lack of length scale separation across the medium thickness, whereas being much less computational time consuming than direct simulations. In particular, the PN simulations permit to conduct statistical studies, e.g. [1], [2], that would be practically impossible to perform from direct simulations.

References

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