Upscaling (un)saturated transport properties in porous materials from pore size distributions

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Résumé

Despite of the recent advances in porous media imaging, the obtaining of a well-resolved 3D network remains challenging for tight porous materials where pore sizes are less than a hundred of nanometers. Therefore, there is still a gap between the nanoscale of the porous network where predicting computational tools have been recently developed and the material macroscopic scale where the tightness of a structure has to be assessed or controlled.

This work aims at upscaling unsaturated transport properties in porous materials solely based on pore size distribution measurements by the mercury intrusion porosimetry (MIP) technique. Even if it is well-known that the MIP technique presents strong drawbacks, artefacts and biases in the pore size distribution characterization, it is often the only alternative to extract pore network information for field materials.

Different authors tried to estimate transport properties from pore size distribution measurements but, in the literature, analyses are usually restricted to intrinsic permeability of the material and the evolution of the apparent permeability with respect to the pressure gradient and to the nature of the fluid considered are left aside. A new model capable to provide the apparent permeability of a porous material to gas, directly from the pore size distribution and from the properties of the gas is firstly discussed [1-2]. Comparisons with experimental data on mortar specimens show that the model can reproduce the intrinsic permeability and its evolution when the material is subjected to mechanical damage, provided the pore size distributions are available. For a given pore size distribution, the evolution of the apparent permeability is also provided by the model and test data with several types of gases compare quite well with the model.

Extension to the transport of different phases (e.g. water and water vapour) is discussed, with a view towards the simulation of nuclear accident in containment vessels. It is shown that small pores that are not affected by damage according to the pore size distribution are of great importance in the evaluation of the relative permeability to liquid and vapour as a function of the saturation. A tentative model based on the percolation of small pores into an

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equivalent homogeneous material is discussed and compared with the existing – standard – approach relying on Van Genuchten relationships [3]. The advantage of the present model is that it relies on the measurement of the pore size distribution and on the physical properties of the considered fluid. The description of permeation does not require any additional fitting parameters. Moreover, such a description may be easily implemented into very large scale computations.

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Mots-Clés: porous media, pore size distribution, intrinsic permeability, apparent permeability, relative permeability