Combined use of finite volume and network modelling for Stokes flow and permeability tensor computation in porous media

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Recent developments in imaging techniques such as X-ray computed micro-tomography make possible 3D imaging of porous media micro-geometry at unrivalled resolutions. After segmentation, the resulting binary images can be used to define the grid necessary to compute the local fluid flow through the pores or the averaged permeability tensor of the porous material. Efficient and accurate codes are available to perform those computations, but at extremely high computational costs (memory and CPU time) when large volumes of data, as presently accessible, are considered.

An alternative to the direct computation of pressure and velocity fields (DCPV) in the 3D image is the use of network models (NM) where the complex pore structure is represented by an equivalent network of pore bodies (PB) connected via pore throats (PT). This method produces a system of linear equations of moderate size that can be easily solved. Then, applicability of NM is not limited by computational costs, but by difficulties in building, from a discretized 3D image, an equivalent network summarizing the relevant topological (connectivity of pore bodies) and geometrical (resistance associated to each pore throat) aspects of a porous medium.

In this work different crucial steps of this process are analysed in depth: starting from a 3D binary image of a porous sample, a skeleton of the pore space is built. This skeleton is analysed to define a graph where nodes correspond to PB and branches to connections intersecting PT. Finally, the partitioning itself is performed to precisely delineate the PB associated to the nodes and the PT. Boundary conditions are considered with particular interest since the NM has to be used for flow modelling and permeability tensor estimation. The resistance associated to each PT is evaluated solving a local flow problem that is theoretically introduced. An original solution is proposed to handle the cases where more than two pores partly share a PT. Application to real examples are presented.

Keywords: porous media, permeability tensor, Stokes flow, network model