Contribution ID: **27**   Type: **Oral Presentation**

Second order deviation of permeability due to unresolved morphological features at the pore scale

Monday, 30 May 2022 14:10 (15 minutes)

Pore-scale dynamics of one phase flow commonly involves adherence (no-slip) boundary conditions at the fluid/solid interface. However, improved modeling such as flows at moderate Knudsen numbers (i.e. for values below 0.1), or homogenization of rock matrix roughness, may require slip conditions [1,2]. It turns out that a lack of knowledge on the rock matrix wall, built by X-Ray micro tomography, leads to the same type of slip conditions

$$v = \frac{\beta}{2}(I - nn) \cdot (\nabla v + \nabla v^T) \cdot n$$

where v is the pore-scale velocity, n is the unit normal vector oriented towards the fluid and β is twice the slip-length.

The macroscopic model corresponding to steady one-phase flow in the creeping regime (Stokes equations) at the pore-scale with the slip condition was derived in [1, 2]. The macroscopic momentum equation corresponds to Darcy's law in which the permeability tensor is slip-dependent. This leads to a computation of an apparent permeability that depends on β and that we denote K_β. This apparent permeability can be expanded in a power series of a Knudsen number, the zeroth-order term identifying to the intrinsic permeability with no slip and the higher order terms to slip-correction tensors, the first one generalizing, for an ideal gas, the classical Klinkenberg correction. All the tensors are given by the solution of coupled closure problems at the successive orders [2]. While this expansion has been addressed in [1] and [2] and used in the case of synthetic geometries, it has been used in large three-dimensional real geometries in [3] in the context of isotropic permeability, that is to say $K_\beta = \kappa_\beta I$ where κ_β is a scalar. In this last case, the expansion

$$\kappa_\beta = \kappa_0 + \beta \lambda_1 + \frac{\beta^2}{2}\lambda_2 + \mathcal{O}(\beta^3)$$

is shown to describe the uncertainty on the permeability values that results from the gray scale uncertainty generated by micro-tomography.
The coefficients λ_k, capturing this uncertainty estimation, are given by the solutions of the Stokes-like closure problems reported in [2] by formal expansion (from averaged equations) and re-established in [3] by asymptotic analysis (two-scale homogenization). They satisfy a non-homogeneous Dirichlet boundary condition (prescribed velocity) at the pore walls, whose value involves the immediate lower order slip momentum.

While the first order of this expansion has been detailed in [3], its second order estimation is provided for the first time in this presentation for operational 3D geometries: we apply our results to the high resolution rock sample studied in [4] and show that the second order brings a significant improvement of the uncertainty estimation on the absolute permeability. These results in a real geometry confirm what was anticipated in [2] for simplified 2D geometries and are relevant as they show the importance of slip at the macroscale.

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[3] S. Perez, P. Moonen, and P. Poncet, On the Deviation of Computed Permeability Induced by Unresolved Morphological Features of the Pore Space, Transport in Porous Media, 2021. doi:10.1007/s11242-021-01713-z

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Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

In person

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