



**HAL**  
open science

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

Sarah Perez, Francisco J Valdés-Parada, Didier Lasseux, Philippe Poncet

### ► To cite this version:

Sarah Perez, Francisco J Valdés-Parada, Didier Lasseux, Philippe Poncet. Second order deviation of absolute permeability due to unresolved morphological features at the pore scale. 14th Annual International Conference on Porous Media Interpore 2022, Khalifa University, May 2022, Abu Dhabi, United Arab Emirates. hal-04159449

**HAL Id: hal-04159449**

**<https://hal.science/hal-04159449>**

Submitted on 4 Jul 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License



Abstract ID : 27

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

### Contenu

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  $\beta$  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  $\beta$  and that we denote  $K_\beta$ . 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  $\kappa_\beta$  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  $\lambda_k$ , 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.

### References

- [1] D. Lasseux, F.J. Valdés-Parada, J.A.O. Ochoa Tapia and B. Goyeau, A macroscopic model for slightly compressible gas slip flow in homogeneous porous media, *Physics of Fluids* 26(5), 053102, 2014. doi: 10.1063/1.4875812.
- [2] D. Lasseux, F.J. Valdés-Parada and M.L. Porter, An improved macroscale model for gas slip flow in porous media, *Journal of Fluid Mechanics* 805, 118-146, 2016. doi:10.1017/jfm.2016.562.

[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

[4] L. Hume, and P. Poncet, A velocity-vorticity method for highly viscous 3D flows with application to digital rock physics, *Journal of Computational Physics* 425, 109910, 2021. doi:10.1016/j.jcp.2020.109910

## Participation

In person

## Country

France

## Student Poster Award

No, do not submit my presentation for the student posters award.

## Time Block Preference

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

## Acceptance of the Terms & Conditions

[Click here to agree](#)

**Auteurs principaux:** PEREZ, Sarah (Universite de Pau et des Pays de l'Adour, E2S UPPA, CNRS, LMAP, Pau, France); Prof. VALDÉS-PARADA, Francisco J. (División de Ciencias Básicas e Ingeniería, Universidad Autónoma Metropolitana-Iztapalapa, Mexico); Dr LASSEUX, Didier (I2M, UMR 5295, CNRS, Univ. Bordeaux, France); Prof. PONCET, Philippe (Universite de Pau et des Pays de l'Adour, E2S UPPA, CNRS, LMAP, Pau, France)

**Orateur:** PEREZ, Sarah (Universite de Pau et des Pays de l'Adour, E2S UPPA, CNRS, LMAP, Pau, France)

**Track Classification:** MS14 - (MS14) Uncertainty Quantification in Porous Media

**Type de contribution:** Oral Presentation

Submitted by **Prof. PONCET, Philippe** on **Friday 10 December 2021**