
Inertial flow in porous media : effect of pressure gradient orientation

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Résumé

Upscaling inertial flows is important for many engineering applications where pressure drops and velocity distribution need to be predicted in porous systems. The most classical model used is the Forchheimer equation that links the superficial velocity with the macroscopic pressure gradient using a global permeability tensor. The latter differs from the intrinsic permeability tensor by taking into account inertial effects of the flow. The Volume Averaging method then allows to write closure problems in order to determine the value of the global permeability tensor (1). However an important challenge is the treatment of the non-linear terms remaining in the closure problems. As a consequence of these non-linearities, closure problems are themselves dependent on the local averaged flow parameters such as the value and orientation of the macroscopic pressure gradient of the flow (2).

First, the influence of the pressure gradient orientation for the characterisation of the global permeability tensor is assessed through the study of test cases. A fully developed laminar flow entering a 2D porous elbow is considered in order to enforce a change of flow direction in the porous medium. The global permeability tensor is characterised using the non-linear closure problems provided by the Volume Averaging method. This approach is compared with diagonal permeability formulations prescribed by commercial CFD softwares that do not take into account flow orientation. The macroscopic simulations are then compared with volume-averaged direct numerical simulations of the fluid flow in the resolved porous domain. Results show that, the general macroscopic model correctly predicts the flow within the porous media, while the diagonal model significantly under-predicts the pressure variation along the elbow with increasing pore Reynolds numbers.

Then, to facilitate the resolution of the non-linear closure problems, a linearised approach for small pore Reynolds number is proposed. One of the main advantages of this method is that it does not require to solve the full closure problems for each value and orientation of the macroscopic pressure gradient (3). The validity of this approach is assessed for various unit cell geometries against numerical solutions of the corresponding non-linear problems, showing excellent agreement for pore Reynolds number up to about one. Finally, generalisation of this linearisation methodology to other types of non-linear flows such as compressible flows is examined.

*Intervenant

References

- (1) S. Whitaker, 'The Forchheimer equation: A theoretical development', *Transport in Porous Media*, vol. 25, pp. 27–61, Sep. 1996
- (2) D. Lasseux, A. A. Abbasian Arani, and A. Ahmadi, 'On the stationary macroscopic inertial effects for one phase flow in ordered and disordered porous media', *Physics of Fluids*, vol. 23, no. 7, p. 073103, Jul. 2011
- (3) M. Pauthenet, Y. Davit, M. Quintard, and A. Bottaro, 'Inertial Sensitivity of Porous Microstructures', *Transport in Porous Media*, vol. 125, Nov. 2018