Geophysical Research Abstracts
Vol. 16, EGU2014-10529-1, 2014
EGU General Assembly 2014

Pore scale simulations for the extension of the Darcy-Forchheimer law to shear thinning fluids

Tiziana Tosco (1), Daniele Marchisio (2), Federica Lince (2), Gianluca Boccardo (2), and Rajandrea Sethi (1)

(1) Politecnico di Torino, Department of Environment, Land and Infrastructure Engineering - DIATI, Torino, Italy (tiziana.tosco@polito.it), (2) Politecnico di Torino, Department of Applied Science and Technology - DISAT, Torino, Italy

Flow of non-Newtonian fluids through porous media at high Reynolds numbers is often encountered in chemical, pharmaceutical and food as well as petroleum and groundwater engineering and in many other industrial applications $(1-2)$. In particular, the use of shear thinning polymeric solutions has been recently proposed to improve colloidal stability of micro- and nanoscale zerovalent iron particles (MZVI and NZVI) for groundwater remediation. In all abovementioned applications, it is of paramount importance to correctly predict the pressure drop resulting from non-Newtonian fluid flow through the porous medium. For small Reynolds numbers, usually up to 1, typical of laboratory column tests, the extended Darcy law is known to be applicable also to non Newtonian fluids, provided that all non-Newtonian effects are lumped together into a proper viscosity parameter $(1,3)$. For higher Reynolds numbers (eg. close to the injection wells) non linearities between pressure drop and flow rate arise, and the Darcy-Forchheimer law holds for Newtonian fluids, while for non-Newtonian fluids, it has been demonstrated that, at least for simple rheological models (eg. power law fluids) a generalized Forchheimer law can be applied, even if the determination of the flow parameters (permeability K, inertial coefficient β, and equivalent viscosity) is not straightforward. This work (co-funded by European Union project AQUAREHAB FP7 - Grant Agreement Nr. 226565) aims at proposing an extended formulation of the Darcy-Forchheimer law also for shear-thinning fluids, and validating it against results of pore-scale simulations via computational fluid dynamics (4). Flow simulations were performed using Fluent 12.0 on four different 2D porous domains for Newtonian and non-Newtonian fluids (Cross, Ellis and Carreau models). The micro-scale flow simulation results are analyzed in terms of "macroscale" pressure drop between inlet and outlet of the model domain as a function of flow rate. The results of flow simulations show the superposition of two contributions to pressure drops: one, strictly related to the non-Newtonian properties of the fluid, dominates at low Reynolds numbers, while a quadratic one, arising at higher Reynolds numbers, is dependent only on the porous medium properties.

The results suggest that, for Newtonian flow, the porous medium can be fully described by two macroscopic parameters, namely permeability K and inertial coefficient β. Conversely, for non-Newtonian flow, an additional parameter is required, represented by the shift factor α, which depends on the properties of both porous medium and fluid, which is not easy to be determined in laboratory tests, but can be in turn calculated from 2D or 3D pore-scale flow simulations, following the approach which was adopted in this work.

References

1. Sorbie, K.S. Polymer-improved oil recovery; Blackie ; CRC Press: Glasgow, Boca Raton, Fla., 1991.

2. Xue, D.; Sethi, R. Viscoelastic gels of guar and xanthan gum mixtures provide long-term stabilization of iron micro- and nanoparticles. J Nanopart Res 2012, 14(11).

3. Bird, R.B.; Armstrong, R.C.; Hassager, O. Dynamics of polymeric liquids. Volume 1. Fluid mechanics; John Wiley and Sons Inc.: New York - NY, 1977.

4. Tosco, T.; Marchisio, D.L.; Lince, F.; Sethi, R. Extension of the Darcy-Forchheimer Law for Shear-Thinning Fluids and Validation via Pore-Scale Flow Simulations. Transport in Porous Media 2013, 96(1), 1-20.