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Numerical investigation of inertial flow in 2D and 3D model porous media

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This work is aimed at the numerical study of inertial effects during Newtonian stationary laminar single-phase flow through both 2D and 3D periodic porous model structures, the applications of which can be found in enhanced petroleum recovery, flow in packed bed reactors, in canopies of urban structures, among many others. The pore-scale flow problem was numerically solved for 2D and 3D model porous media composed of fluid domains containing solid inclusions for a wide range of Reynolds numbers. Based on the macroscopic model obtained by upscaling the stationary Navier-Stokes equations, macroscopic properties such as permeability and inertial correction vector were determined [1].

The globally disordered structures generated in this work are more disordered, compared to the ordered and locally disordered structures used in previous studies [1][2]. For clarity, when the centres of the inclusions are randomly distributed, the structure is Globally Weakly Disordered (GWD); when the size of the obstacles is also distributed randomly, the structure becomes Globally Strongly Disordered (GSD).

Intensity of inertia is characterized by the magnitude of the dimensionless inertial correction vector, $\boldsymbol{f_c}$, which reflects the inertial force exerted on the structure. Flow regimes with different intervals of validity can be identified through the relationship between the x-component of $\boldsymbol{f_c}$ (f_{cx}) and the macroscopic Reynolds number Re_k. In addition, the flow regimes are shown to be correlated with the dependence of the hydraulic tortuosity upon the Reynolds number. This confirms the results reported in [2] and [3], which were obtained for simpler geometries. The 3D effect on flow through spatially periodic porous media is examined in comparison to the 2D pore geometries.

Three main conclusions can be drawn from the analysis. The flow inertia increases as more disorder was introduced into the pore structures in both 2D and 3D structures. The flow inertia in 2D structures is much stronger than that in 3D structures. The influence of the size distribution of the obstacles on the flow is not very significant for both 2D and 3D simulations, since minor differences are observed for the flow properties (flow inertia, hydraulic tortuosity, etc.) with or without the size distribution.

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