# Numerical Investigation of Unsteady Inertial and Turbulent Flows through Porous Media: Pore-scale DNS, Flow Analyses and Upscaling


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### Abstract


Unsteady inertial and turbulent flows through packed beds and porous media are encountered in a wide range of natural and engineered systems, however our general understanding of moderate and high Reynolds number flows is limited to mostly empirical and macroscale relationships. In this work, the pore-scale flow physics, which are important to properties such as bulk mixing performance and permeability, are investigated using direct numeric simulations (DNS) of flow through a periodic face centered cubic (FCC) unit cell at pore Reynolds number of 300, 500 and 1000. The simulations are performed using a fictitious domain, which uses non-body conformal Cartesian grids, with resolution up to D/δ=250 (354^3 cells total). Eulerian and Lagrangian correlations are obtained to find the integral length and time scales. The integral length scales are found to be less than 10% of the bead diameter for all Reynolds numbers. Moreover, angular multiscale statistics are computed to quantify the dispersion by estimating the curvature angles along fluid particle trajectories at different time lags. An asymptotic angle as long time behavior was observed to be different from the result of isotropic turbulence, distinguishing the influence of the geometry confinement. And a Monte-Carlo based stochastic model is developed to predict such asymptotic angle. Finally, the method of volume averaging (MVA) is applied to derive the macroscopic NS equations. And an algebraic model is proposed by upscaling the DNS results.


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