Upscaling of Filtration in Rigid Porous Media. Investigation of Effective Permeability of Periodic Granular Medium.

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ABSTRACT: We used a homogenization procedure, which exploits a multi-scale structure possessed by a solid porous medium, a «micro-scale» comparable to the pore size and a «macro-scale» associated with the global size of the body, to carry out a multi-scale asymptotic analysis. In modeling fluid flow through rigid granular medium we derived the governing equations for all scales and got averaged macroscopic equations with effective coefficients, which were the components of effective permeability tensor. The derivation of the effective permeability was reduced to the solution of periodic boundary problems in the unit cell. In order to solve this problem we developed analytically-numerical method, based on approximation of the solution by shape functions, which exactly satisfied interface conditions on boundaries between different phases of flow. For some characteristic elements of periodic structure shape functions were obtained in closed analytical form. This form was conditioned by the implementation of certain representation for pressure and velocity being special form of Helmholtz representation, as well as by special structure of auxiliary potentials, based on introduced harmonic polynomials. Final form of the solution was approximated by the series of shape functions. This enabled us to make high accuracy approximation of 3D cell problem solution.