Computational Homogenization for Hierarchically Arranged Porous Media

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Abstract

We consider fluid flow in a hierarchically organized structure which by constituted as fractured porous medium at several hierarchies and scales, cf. [3,4]. In the present work we pursue a modelling approach [1] which was developed for double porosity media in [2]. We apply a two-level homogenization procedure to the Stokes flow with modified, scaled viscosities in the micropores. Two parameters, ε associated with the microstructure, and δ, associated with the mesoscopic channels, or fractures, are involved in the analysis. The 1st step of the asymptotic analysis for $\varepsilon \to 0$ leads to a model describing coupled Darcy flow in the porous medium and Stokes flow in the fractures, whereby reduced Saffman transmission conditions hold on the interface between the two porosities. Reiteration of this homogenization scheme is considered in the 2nd step for $\delta \to 0$ to obtain the Darcy-Brinkman model describing the macroscopic flow.

As a new contribution, we consider a mesoscopic structure with two disconnected systems of fractures (or channels) which has been motivated by the lobular units of the liver. These units are constituted by the capillary network of the sinus which is connected to two mutually separated systems of venulae representing the lower-most hierarchies of the portal and hepatic perfusion trees.

We discus computational issues related to the problem discretization using the finite element method. In particular, we illustrate the macroscopic model response for given geometries of the micropores and the mesoscopic channels. Consequently, for a selected position in the porous structure characterized by given $\varepsilon > 0$ and $\delta > 0$, the flow reconstruction can be performed in the local mesoscopic and microscopic volumes.

References

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