Averaged model for mass and momentum transport in porous media with evolving heterogeneities

Morgan Chabanon*[1], Philippe Angot[2], J. Alberto Ochoa-Tapia[3], and Benoit Goyeau[1]

[1]Laboratoire d'Énergétique Moléculaire et Macroscopique, Combustion – CentraleSupélec, Université Paris-Saclay, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UPR288 – France

[2]Institut de Mathématiques de Marseille – Aix Marseille Université, Ecole Centrale de Marseille, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR7373, Ecole Centrale de Marseille : UMR7373, Aix Marseille Université : UMR7373 – France

[3]Universidad Autónoma Metropolitana [Mexico] – Mexique

Résumé

Macroscopic transport equations and effective properties valid in the bulk of porous media have been derived extensively using various up-scaling and homogenization methods. They all fundamentally rely on the separation between the length scale at which the porosity evolves spatially and the length scale of the representative volume. However, many relevant applications in porous media display fast evolving heterogeneities that violate this length scale separation, showing non-negligible porosity gradients. These include heterogeneous and stratified porous media, as well as interfaces between porous and fluid or solid phases.
In this work, the separation between the length scales of the porosity gradient and the representative volume is relaxed. The macroscopic mass and momentum transport equations are derived without this constraint, yielding corrections terms involving spatial derivatives of the porosity. The definitions of the permeability and effective diffusivity are generalized, and a new set of suitable closure problems are obtained. These closure problems also exhibit extra terms implying porosity derivatives.
First, the closure problems were solved numerically on representative unit cells for various space-dependent porosity functions. For the cases studied, solutions of the closure problems gave a quasi-negligible correction of the effective parameters compared to the ones without porosity variations. Then macroscopic transport equations were solved numerically and compared with results from direct numerical solutions where the obstacles were fully resolved. The results show that the macroscopic corrections involving the porosity derivative are required to correctly predict the velocity and pressure fields when the flow is oriented along the porosity variations, but are negligible if it is oriented orthogonally. Overall, this works highlights the importance of the corrections involving porosity derivatives in the macroscopic transport equations in the presence of evolving heterogeneities.

*Intervenant