Asociación Argentina
de Mecánica Computacional

Resúmenes de Mecánica Computacional Vol I, pp. 95-95
C.I. Pairetti, M.A. Pucheta, M.A. Storti, C.M. Venier (Eds.)
P. Kler, S. Márquez Damián, P. Gamazo, G. Buscaglia (Issue eds.)
Rosario, November 5-8, 2024

ASSESSING ELECTROOSMOTIC FLOW IN POROUS MEDIA WITH MULTI-SCALE TECHNIQUES FOR PAPER-BASED MICROFLUIDICS

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Keywords: multiscale formulations, RVE, electroosmotic flow, effective electroosmotic permeability, paper-based.

Abstract. In this work, multiscale techniques to model the electroosmotic flow in porous materials with paper-like microstructures are studied and applied. The multiscale technique is based on the definition of a representative volume element (RVE) of the material to be modeled. In this case, the microstructure is built from connected channels where the fluid moves inside the void of the porous material (microscale). At the microscale, the velocity and pressure are solved under incompressible flow conditions in the Stokes regimen with a volumetric force term associated with Coulombic forces. Such forces are calculated by solving the electric field via the charge conservation equation. However, instead of directly applying the volumetric force over the fluid charges, which are confined to the Debye layer, the electroosmotic velocity is included in the fluid dynamic problem as a boundary condition, significantly reducing the computational demand. This approximation is valid due to the fact that the Debye layer is extremely thin (in the order of nanometers) compared to the channel width (in the order of micrometers), for the solutions and substrates used in paper-based microfluidics. Afterward, once the homogenized velocity field of the microscale problem has been obtained, an effective electroosmotic permeability is estimated in the macroscale problem, as the relation between the flow rate and the electric field. To validate the results, a comparison is made with results reported in the literature. This study aims to investigate the limitations of this methodology and to identify necessary modifications that should be made to the assumptions and formulations for accurate modeling of electroosmotic flow in paper-based microfluidic applications.

ISSN: 2591-3522