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Direct Numerical Modelling Of Capillary Driven Multiphase Flow at the Embedded Steel - Porous Media Interface

Luka Malenica [1], Zhidong Zhang [1], Ueli Angst [1]
[1] Institute for Building Materials (IfB), ETH Zurich
Leopold-Ruzicka-Weg 4, 8093 Zurich, Switzerland
lmalenica@ethz.ch; zhidongz@ifb.baug.ethz.ch; ueli.angst@ifb.baug.ethz.ch

Extended Abstract

Multiphase flow through porous materials is an important field of study in a broad range of applications. One of such applications is understanding and predicting corrosion mechanisms inside reinforced porous materials, such as soil or concrete, where air-water distribution at the steel surface is directly related to corrosion processes and has a great impact on durability of reinforced structures [1].

Prediction of water transport and retention throughout pore systems is generally based on traditional models relying on either Darcy scale modelling, such as Richards equation [2] or simplified pore scale modelling, such as bundle of capillary tubes or pore-network modelling [3]. However, such models are not capable of providing detailed insight into water distribution at the steel-porous media interface which is crucial to understanding of relevant degradation mechanisms such as corrosion.

One approach that can overcome mentioned limitation of traditional models is direct numerical modelling of multiphase flow directly at pore scale [4]. Such an approach solves the full set of Navier-Stokes equations which accurately describes multiphase flow by directly resolving fluid-fluid interfaces and contact lines of fluid phases with solid boundaries, such as contact between air, water and solid (both porous skeleton and steel in our case). Moreover, these models are capable to account for complex microstructure heterogeneities of real pore structures obtained by pore-scale imaging, such as X-ray microtomography or FIB-SEM techniques.

In this work, OpenFOAM based volume-of-fluid (VOF) solver is used to perform high-fidelity direct numerical simulations of gas-liquid multiphase flow inside different reinforced porous media, such as reinforced soil or concrete. Both synthetic and realistic (imaged-based) pore structures, as well as different material properties were studied. Even that direct numerical modelling approach cannot be used to predict flow over full scale of interest (mostly due to high computational cost and size limitations of pore-scale imaging), combining detailed resolution of fully dynamic pore-scale multiphase processes with realistic 3D geometries of pore space enables us deeper insight and consistent explanation of particular processes that are still not well understood.

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