Coupling porous medium and free flow systems. Numerical methods.

Iryna Rybak

Institute of Applied Analysis and Numerical Simulation
University of Stuttgart, Germany

Coupled porous medium and free flow systems arise routinely in science and engineering (evaporation from the soil influenced by the wind, filtration processes, fuel cells). In these flow domains, the processes evolve on different scales in space and time that requires an application of different models for each flow system and an accurate treatment of transitions between them at the interface.

In the free flow region, the Navier–Stokes or Stokes equations are typically used to describe momentum conservation while Darcy's law is applied as an approximate conservation of momentum equation in the porous medium. A suitable set of interface conditions has to be prescribed at the fluid-porous interface in order to couple the two flow domains. These are typically mass conservation across the interface, balance of normal forces and the Beavers–Joseph condition which establishes the connection between the free flow velocity and the porous medium velocity tangent to the interface and is an additional condition to couple equations of different orders.

Various discretization techniques such as finite element methods, mixed finite element methods, finite volume schemes, control volume finite element discretizations, discontinuous Galerkin methods and their combinations can be applied to the coupled Stokes–Darcy problem. Such multiphysics problems can be solved using the monolithic approach or considering different decoupled schemes. Since the fluid velocity in the free flow domain is usually much higher than in the porous layer, it is reasonable to apply a multiple time-step technique: to compute fast solutions using a small time step and consider a larger time step for slow solutions.

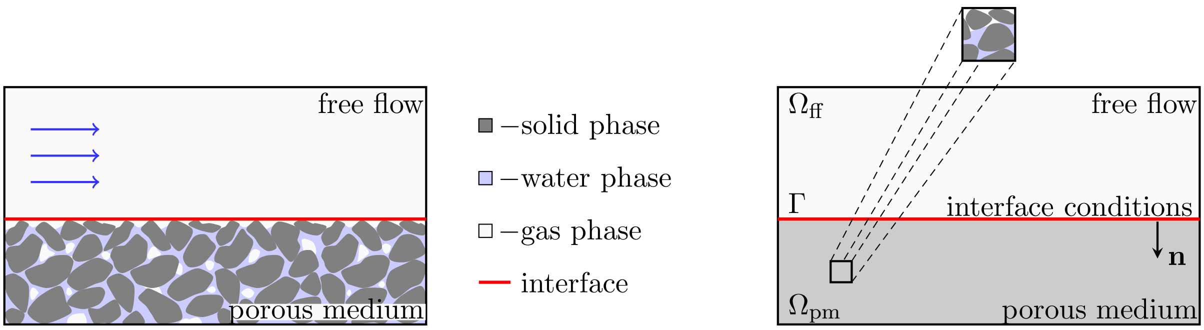

Figure 1: Flow system description: microscale (left) and macroscale (right).

The lecture is mainly devoted to numerical solution of the coupled free flow and porous medium flow problems, starting with stationary problems and then considering nonstationary flows, species transport, multiple fluid phases and nonisothermal flows, considering both the monolithic approach and decoupled schemes with single and multiple time steps.