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Generalized coupling conditions for arbitrary flows to the fluid-porous interface

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Coupled systems containing a free-flow region and a porous-medium domain appear in many technical applications, biological and environmental settings, e.g., industrial filtration, cell proliferation, surface water/groundwater flow. The interaction between the free flow and the porous-medium flow is dominated by the interface driven processes. Thus, for accurate modeling and numerical simulation of such coupled flow problems the correct choice of coupling conditions at the fluid-porous interface is crucial.

We use the Stokes equations to describe the fluid flow in the free-flow region and Darcy's law in the porous-medium domain. In order to couple the two different systems of equations, the conservation of mass, the balance of normal forces and the Beavers-Joseph coupling condition on the tangential velocity component, which was proposed for flows parallel to the fluid-porous interface, are typically applied. However, this set of interface conditions is not suitable for arbitrary flows to the fluid-porous interface [1].

In this talk, we present new, generalized coupling conditions for the Stokes-Darcy problem, which are valid for arbitrary flow directions to the fluid-porous interface [2]. These conditions are derived rigorously using the theory of homogenization with two-scale asymptotic expansions and boundary layers. Under the assumptions on parallel flow to the porous bed, the developed generalized interface conditions reduce to the ones proposed by Jäger and Mikelić [3]. All coefficients appearing in the new coupling conditions are computed numerically based on the pore geometry of the coupled system and are independent of the macroscopic flow direction. The generalized conditions are validated using pore-scale resolved simulations [2]. The developed coupling conditions are compared to the classical ones highlighting the advantages of the new conditions. The well-posedness of the Stokes-Darcy problem with new interface conditions is studied.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

[1] E. Eggenweiler and I. Rybak: Unsuitability of the Beavers-Joseph interface condition for filtration problems. J. Fluid Mech. 892, A10, 2020.

[2] E. Eggenweiler and I. Rybak: Effective coupling conditions for arbitrary flows in Stokes-Darcy systems. SIAM Multiscale Model. Simul. (in press), 2021.

[3] W. Jäger and A. Mikelić: Modeling effective interface laws for transport phenomena between an unconfined fluid and a porous medium using homogenization. Transp. Porous Media, 78, 489-508, 2009.

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