Control-Volume Finite-Element Schemes for Coupling Free Flow with Porous-Medium Flow

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Exchange processes across a porous-medium free-flow interface occur in a wide range of environmental, technical and bio-mechanical systems. In the course of these processes, flow dynamics in the porous domain and in the free-flow domain exhibit strong coupling, often controlled by mechanisms at the common interfaces. In this work, we focus on the two-domain approach, which decomposes the problem into two disjoint subdomains. The free-flow region is described by the Navier-Stokes equations while Darcy's or Forchheimer's law is used in the porous-medium subdomain. Appropriate coupling conditions are formulated at the common interface, which enforce the conservation of mass, momentum and energy.

In this work, we present a novel mass and momentum conservative control-volume finite-element (CVFE) framework for the discretization of the free-flow subdomain. Furthermore, a new approach to couple schemes belonging to this framework with a vertex-centered finite-volume method (Box method), used for solving Darcy flow in the porous medium, is presented. This work is therefore an extension of the work presented in [1, 2], where a staggered grid approach has been used to discretize the free-flow region. One of the main advantage of the novel control-volume finite-element schemes and the new coupling approach is its flexibility in terms of realization of coupling conditions. Such conditions are dependent on effective parameters such as the Beavers-Joseph coefficient [4] or, for generalized conditions, those developed in [3]. Determining such effective parameters from detailed pore-scale simulations using closure relations and integration into effective data-driven parametrizations is ongoing research. First results related to these topics are presented and discussed for various test cases, ranging from convergence tests to real applications.

References

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