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Efficient solution strategies for a generalized coupled fluid-porous problem

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Coupled fluid-porous systems appear routinely in environmental, biological, and industrial applications. The flow interaction between the free fluid and the porous medium is strongly interface driven and can be described by the sharp interface or the transition region concept. Classical interface conditions based on the Beavers–Joseph approach are valid only for unidirectional flows parallel or perpendicular to the fluid-porous interface.

In this work, we present a coupling concept which is suitable for arbitrary flow directions. We consider a narrow transition region between two flow domains and derive a hybrid-dimensional Stokes–Brinkman–Darcy model (Ruan & Rybak, FVCA, 2023). The transition zone resolves the storage and transfer of mass, momentum, and energy and can be regarded as a complex interface. We validate the proposed coupling concept numerically against the pore-scale resolved simulations. To solve the coupled problem efficiently, we develop and investigate several preconditioners.

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References

Ruan, Linheng, and Iryna Rybak. “Stokes–Brinkman–Darcy Models for Coupled Free-Flow and Porous-Medium Systems.” International Conference on Finite Volumes for Complex Applications. Cham: Springer Nature Switzerland, 2023.

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