Enriched Finite Volume Methods
- Taylored Test Spaces for Interface Problems -

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ABSTRACT

We present a fully-implicit and stable finite element and finite volume scheme for the simulation of freely moving particles in a fluid. The developed method is based on the Petrov-Galerkin formulation of a vertex-centered finite volume method on unstructured grids. Identification with a corresponding finite element bilinear form finally enables the derivation of a finite element method for particulate flow. Appropriate extension of the ansatz and test spaces lead to a formulation comparable to a fictitious domain formulation. In contrast to most fictitious domain methods no additional Lagrange multipliers or artificial external forces need to be introduced for the fluid-solid coupling. The interface forces are implicitly imposed through the original bilinear form for the fluid. The surface integrals of the finite volume scheme enable a natural incorporation of the interface forces. The extended scheme treats the particles as rigid fluid and the resulting system of equations does not possess saddle-point structure. As a result, only one single solve for the derived linear system for the fluid together with the particles is necessary and the proposed method does not require any fractional time stepping scheme to balance the interaction forces between fluid and particles. For the linear Stokes problem we will prove the stability of both schemes. Moreover, for the stationary case the conservation of mass and momentum is not violated by the extended scheme, i.e. conservativity is accomplished within the range of the underlying, unconstrained discretisation scheme. The scheme is applicable for problems in two and three dimensions.