Multiscale Finite Volume Formulation for Compositional Flows

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The MultiScale Finite-Volume (MSFV) method has evolved quite significantly in the last few years (e.g. [1-3]) and is considered as a promising framework for next-generation reservoir simulation. To date, however, the MSFV developments have focused on immiscible two-phase flow. Moreover, in the current MSFV framework, a standard sequential-implicit scheme is usually employed to resolve the nonlinear coupling between the flow (pressure and total-velocity) and transport (saturation) problems.

In this work, we present a new multiscale sequential-implicit formulation for multi-component transport across multiple fluid phases. The new formulation resolves strong coupling between the flow and transport problems in a robust and efficient manner. We employ an overall-composition formulation, in which the pressure equation is obtained by adding the component mass-conservation equations (total mass balance). The resulting pressure equation includes several coefficients that depend on the composition and saturation distributions in a manner that is quite different from the standard pressure equation. Also in contrast to the existing multiscale approaches, the transport equations are also cast in terms of the overall mass fraction. The new formulation is weakly sensitive to the appearance or disappearance of fluid phases. The coupling between the discrete equations of the flow and transport problems is performed in a consistent and locally conservative manner, and this allows one to terminate the iterations before tight residual tolerances are reached. This mass-conservative property is crucial for the efficiency of the multiscale approach for modeling compositional displacements in large heterogeneous reservoirs. Numerical test cases are provided first to validate the consistency of the proposed simulation strategy, and then to study the efficiency of the devised MSFV formulation. We demonstrate that the developed MSFV method captures the transient as well as the steady state pressure solutions accurately. Compared with the existing MSFV methods, the new formulation leads to significant improvements in obtaining efficient solutions for the problems with strong nonlinear coupling between the multiphase flow, multi-component transport, and equilibrium phase behavior.

References

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