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**PROCEEDINGS**

# Numerical Simulation of Multiphase Flow in Subsurface Reservoirs: Existing Challenges and New Treatments

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**ABSTRACT**

Two or multiple phases commonly occur as fluid mixture in petroleum industry, where oil, gas and water are often produced and transported together. As a result, petroleum reservoir engineers spent great efforts in the development and production of oil and gas reservoirs by conducting and interpolating the simulation of multiphase flows in porous geological formation. Meanwhile, environmental scientists use subsurface flow and transport models to investigate and compare for example various schemes to inject and store $CO_2$ in subsurface geological formations, such as depleted reservoirs and deep saline aquifers. In this work, we first present an introduction of numerical simulation of subsurface multiphase flow and its challenges including multiscale heterogeneity, strong and unbalanced nonlinearity, solution discontinuity, local mass conservation, numerical stability and bound preservation. For example, bound preservation is a desired basic property of numerical solutions but often not easy to have. In this basic requirement, it is desired to have the predicted physical quantities sit within a physically meaningful range. Specifically, the predicated saturation should sit between 0 and 1 while the predicated molar concentration should sit between 0 and the maximum value allowed by the equation of state. Unfortunately, popular simulation methods used in the industries do not preserve physical bounds. A commonly used fix to this problem is to simply apply a cut-off operator (say, to the computed saturation) at each time step, i.e., to set the saturation to be zero whenever it becomes negative, and to set it to one whenever it becomes larger than one. However, this cut-off practice does not only destroy the local mass conservation, but it also damages the global mass conservation, which seriously ruins the numerical accuracy and physical interpretability of the simulation results. After going through a number of well-known challenges, we present three frameworks based on our recent works to address some of these challenges. The first one to present is our recently-proposed bound-preserving, phase-wise locally conservative IMPES-like semi-implicit method for two-phase flow in porous media [1]. In addition, we also present our framework on unconditionally bound-preserving, phase-wise locally conservative fully-implicit method for porous media multiphase flow [2,3]. Finally, we present our study on a series of deep learning methods as applied to phase behavior calculation, which can greatly speed up the compositional multiphase flow simulation [4].

**KEYWORDS**

Conservative numerical methods; multiphase flow; reservoir simulation; physics-preserving methods; deep learning

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**References:**

1. Chen, H., Kou, J., Sun, S., Zhang, T. (2019). "Fully mass-conservative IMPES schemes for incompressible two-phase flow in porous media", *Computer Methods in Applied Mechanics and Engineering, 350,* 641-663.
2. Li, Y., Yang, H., Sun, S. (2022). "Fully implicit two-phase VT-flash compositional flow simulation enhanced by multilayer nonlinear elimination", *Journal of Computational Physics, 449,* 110790.
3. Yang, H., Li, Y., Sun, S. (2020) "Nonlinearly preconditioned constraint-preserving algorithms for subsurface three-phase flow with capillarity", *Computer Methods in Applied Mechanics and Engineering, 367,* 113140.
4. Zhang, T., Li, Y., Li, Y., Sun, S., Gao, X. (2020) "A self-adaptive deep learning algorithm for accelerating multi-component flash calculation", *Computer Methods in Applied Mechanics and Engineering, 369,* 113207.