An Explicit Algorithm for the Simulation of Multiphase Fluid Flow in the Subsurface

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Abstract

The present work deals with the simulation of multiphase fluid flow in the subsurface using an original approach based on the analogy with kinetically-consistent finite difference schemes and the quasigasdynamic system of equations [1]. The proposed model accounts for gravitational and capillary forces as well as possible heat sources. As the temperature of all phases and of the rock is identical the system of equations includes a single equation of the total energy conservation.

The phase continuity equation gets a regularizing term and a second order time derivative with small parameters. The equation type is changed from parabolic to hyperbolic. Numerical implementation involves a three-level explicit scheme with a rather mild stability condition. Some large-scale problems (e.g., oil recovery with combustion fronts, phase transitions, complicated functions of the relative phase permeability) require calculations with very small space steps what strictly constrains the time step. Then explicit schemes can surpass implicit schemes used in standard solution methods like IMPES or SS. Besides explicit algorithms are preferable for HPC.

Verification is performed by a drainage test problem [2] concerning two-phase (water-air) infiltration due to the gravity. A good agreement of numerical results with [2] is obtained. To investigate an influence of thermal effects the simulation of three-phase (water-oil-air) flow in a porous medium with a hot water source on the boundary has been fulfilled.

Computations on HPC confirmed high parallelization efficiency of the approach developed.

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References

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