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A new sequential method for three-phase immiscible flow in poroelastic media

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ABSTRACT

A new computational model is developed to solve three phase immiscible compressible flow in strongly heterogeneous poroelastic media. Within the context of the iterative coupled formulation based on the fixed stress split algorithm the governing equations are decomposed into three subsystems associated with the geomechanics, hydrodynamics and transport problems. The hydrodynamics involves an overall compressibility which plays essential role in the magnitude of additional source in the pressure equation associated the time derivative of the total mean stress. We show that the additional coefficients in the source can be decomposed into a rock/grain and fluid components involving the formation volume factors of each phase. The flow equations are written in a proper conservative form for application of mixed-hybrid formulation whereas the nonlinear coupling between flow and transport is handled by a proper sequential iterative scheme. A new post-processing approach is proposed to update the Lagrangian porosity based on the freezing of the total mean stress which reproduces the one-way formulation in a straightforward fashion under the stationarity of the total mean stress. The geomechanical subsystem is also discretized by a mixed formulation based on the decomposition of the effective stress into spherical and deviatoric components in order to handle the nearly-incompressible undrained limit. The system of conservation laws for the liquid saturations is rephrased in an alternative form for an appropriate operator splitting method, leading to the appearance of an extra source term arising from the transient behavior of the Lagrangian porosity induced by the geomechanical coupling. Within the framework of a predictor–corrector scheme, the predictor step is discretized by an extended version of a higher order central-upwind scheme whereas the corrector, which captures the influence of rock skeleton deformation upon transport, is captured by a Godunov splitting. The potential of the new computational model is illustrated in numerical simulations of water-flooding and of WAG (Water Alternating Gas) injection problems in poroelastic media. Numerical results illustrate precisely the role of the transient nature of the total stress upon subsidence, rock compaction, oil and gas production and finger grow in primary and secondary recovery regimes.

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