A NEW ONE-WAY CONSERVATIVE NUMERICAL MODEL FOR THREE-PHASE FLOW IN POROELASTIC MEDIA

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ABSTRACT. A new computational model is developed for solving three phase compressible flow in strongly heterogeneous poroelastic media. The model begins by addressing the fully-coupled formulation, characterized by the extension of the Black-0il model to deformable porous media, and processed within the context of the fixed stress split algorithm [2,3] wherein the Lagrangian porosity is computed using the constitutive law proposed by Coussy [4] and the volumetric strain eliminated from the effective stress principle [1]. Such procedure gives rise to a new iterative formulation of Black Oil type wherein the original fully-coupled model is decomposed into three subsystems associated with the hydrodynamics, geomechanics and the set of conservation laws for the saturations of the liquid phases. The hydrodynamics is governed by a new form of the pressure equation with an additional source term arising from the evolution of the total stress premultiplied by saturations and formation volume factors of the fluid phases. The evolving algorithm is constructed based on implicit discretization of the hydrodynamics and explicit for the saturations. The nonlinearities inherent to the coupling between pressure and saturation equations are handled by a proper sequential iterative scheme. Furthermore, the system of conservations laws is rephrased in an alternative form with an extra source term arising from the transient Lagrangian porosity induced by the geomechanical coupling. For the discrete time evolution of such system we propose a fractional-step method based on Goudonov or Strang splitings. The predictor step is discretized by a higher order finite volume method whereas the corrector captures the influence of the geomechanics upon transport quantified by the source term in the system of hyperbolic equations. A reduced version of the new iteratively coupled method, based on the one way formulation applied to incompressible liquid phases and a fully compressible gas phase, is discretized by sequential locally conservative numerical schemes. Numerical simulations of WAG (water alternate gas) injection problems in poroelastic media are performed showing the potential of the methodology proposed herein.

Keywords: Three-phase flow, geomechanical coupling, fixed stress split, locally conservative numerical methods, fractional-step methods

Mathematics Subject Classifications (2010): Fluid Mechanics, Mechanics of Deformable Solids, Numerical Analysis

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