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Coupled multiphase flow and geomechanics simulation of hydrate dissociation using FVM-FEM co-located variables arrangement

Rahul Samala and Abhijit Chaudhuri
Indian Institute of Technology Madras, Department of Applied Mechanics, India (rsamala2@gmail.com)

Natural gas hydrates, which are ice like crystalline solids, contain tremendous amount of potential hydrocarbon gas. Gas recovery through hydrate dissociation can be achieved through depressurization, inhibitor injection and thermal stimulation. The hydrate dissociation by depressurization involves significant pressure and temperature gradients as the dissociation process is highly endothermic. The destabilization of solid hydrate into fluid constituents causes loss of cementation which can alter the stress field which in turn changes the porosity and permeability of the hydrate bearing medium causing subsidence. In the present study, a thermo-hydro-mechanical-chemical (THMC) coupled numerical simulator is developed accounting for the hydrate phase change kinetics, non-isothermal multiphase flow and geomechanics. The point centered or node centered finite volume method is used for space discretization of flow and energy equations while the finite element method is used for stress equilibrium equation. This procedure requires the flow and mechanics variables to be co-located. The finite volumes are constructed around the flow variables defined at nodes while the finite element is defined by the corner nodes. The volumetric strain rate term in the flow equations, which couples the flow and geomechanics equations, is evaluated by interpolating the volumetric strains calculated over the finite elements to the finite volumes. Our simulations show that this procedure results in a stable convergence of the solution without the need for any stabilizing terms due to co-located variable arrangement. Our simulations also show that the iterative coupled approach, where the flow and geomechanics equations are solved separately and sequentially, gives stable convergence without any additional split terms due to sequential but iterative solving of the coupled equations.