

Coupled Flow and Mechanics in Porous and Fractured Media
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Flow through deformable porous materials is coupled to solid mechanics by virtue of Terzaghi's principle of effective stress, wherein stresses in porous materials are borne by both pore pressure and the stress field in the solid skeleton. Some applications of current interest come from such diverse areas as geologic sequestration of anthropogenic CO₂, hydrofracturing for stimulation of hydrocarbon reservoirs, and modeling electrochemistry-induced swelling of fluid-filled porous electrodes. Induced stress fields in any of these applications can lead to structural failure and fracture. The ultimate goal of this research is to model evolving faults and fracture networks and flow within the networks while coupling to flow and mechanics within the intact porous structure.

We report here on a new computational capability for coupling of multiphase porous flow with geomechanics including assessment of over-pressure-induced structural damage. The geomechanics is coupled to the flow via the variation in the fluid pore pressures, whereas the flow problem is coupled to mechanics by the concomitant material strains which alter the pore volume (porosity field) and hence the permeability field. To facilitate coupling with disparate flow and mechanics time scales, the coupling strategy allows for different time steps in the flow solve compared to the mechanics solve. If time steps are synchronized, the controller allows intra-time-step iterations. The coupling is dynamically controlled by monitoring a norm measuring the degree of variation in the deformed porosity, thereby controlling the frequency of mechanics solves compared to flow solves.

In addition to these bulk couplings, a pure Lagrangian explicit-dynamics computational methodology has been developed that can simulate the pervasive dynamic failure of materials and structures by allowing new cohesive fracture surfaces to nucleate at the interelement faces of a random polyhedral mesh. The explicit facet representation of fractures within this approach is advantageous for modeling coupled fluid-flow within the evolving fracture networks. Currently, the flow within the fractures is modeled using Reynold's lubrication approximation. The fractures are represented as two-dimensional surfaces with spatially varying aperture. Representative applications will be presented demonstrating coupled flow and mechanics with one-way coupling to drive the dynamic failure simulation of discrete fracture generation and growth.

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