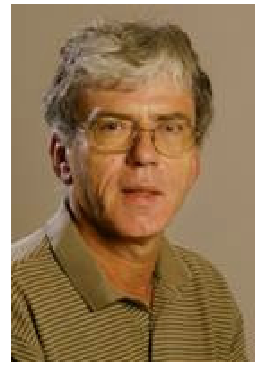
The Maurice A. Biot Lecture

Department of Civil Engineering & Engineering Mechanics, Columbia University
Engineering Mechanics Committee, ASCE Metropolitan Section
Engineering Mechanics Institute, ASCE

ONE-WAY VERSUS TWO-WAY COUPLING IN RESERVOIR - GEOMECHANICAL MODELS



Professor Jean H. Prévost
Princeton University

November 19, 2014 (3:30-4:30 pm)
Davis Auditorium, 412 CEPSR

Abstract: Procedures to couple reservoir and geomechanical models are reviewed. The focus is on immiscible compressible non-compositional reservoir - geomechanical models. Such models require the solution to: coupled stress, pressure, saturation and temperature equations. Although the couplings between saturation and temperature with stress and fluid pressure are "weak" and can be adequately captured thru staggered (fixed point) iterations, the couplings between stress and pressure equations are "strong" and require special procedures for accurate integration. Issues related to both simultaneous integration and sequential integration of pressure and stress equations are investigated. It is shown that simultaneous integration can be achieved by computing the contribution to the coupled Jacobian matrix thru finite differencing of the residual equations. Forming the Jacobian matrix can also be avoided thru a partitioned CG iterative solution procedure of the Schur complement matrix. Iterative sequential integration (fixed point iterations) schemes of pressure and stress equations are then discussed, and detailed algorithms are provided. Assessment of the accuracy of such iterative procedures is made thru comparison with available exact analytical solutions for the half-space consolidation. The iterative sequential procedure (one-way coupling iteration) is shown to require an unreasonably large number of iterations (>50) to capture accurately coupling effects. We conclude that two-way coupling (i.e., simultaneous integration) of pressure and stress equations is required if poromechanical effects are to be captured accurately. In our work we typically use a Galerkin implementation of both pressure and stress equations with equal order interpolant for both pressure and solid displacements. However, most (if not all) reservoir simulators use a finite volume implementation of the pressure equation. Therefore, we also address issues related to the interface between a Galerkin vertex-centered Geomechanical model with a Reservoir finite volume implementation of the pressure equation by studying the interface with both a cell-centered and a vertex-centered (often referred to as CVFEM in the Petroleum Engineering literature) finite volume implementation of the pressure equation. The elemental contribution to the Jacobian matrix is again computed through numerical finite differencing of the residuals. We show that poromechanical effects can be captured accurately with a finite volume implementation in both 2D and 3D structured and unstructured meshes. Finally, the coupling effects in a field case are investigated: CO_2 injection at In Salah, Algeria where CO_2 is injected at a temperature (50 dgC) below the resident brine reservoir (90 dgC) temperature. Surface uplift displacements and induced tensile stresses in the caprock computed with both a fully two-way coupled scheme versus a one-way scheme are compared.

Biosketch: Professor Jean H. Prévost has over 35 years of experience in the areas of computational solid mechanics, wave propagation and transient effects in porous media, nonlinear constitutive theories, dynamic instabilities and localization of deformations in solids, thermo-elasticity, electro-magneto-solid interaction effects and finite element methods. He is currently doing research on topology optimization, delayed fracture in MEMS, cracks propagation in microstructures, and reservoir models for CO_2 sequestration in deep saline aquifers. He has published over 250 technical papers in refereed journals and conference proceedings.

The Maurice A. Biot Lecture was established at Columbia University in 2004 in remembrance of the late Professor Maurice Anthony Biot and his renowned achievements as an engineer, physicist, and applied mathematician. Biot was a professor of mechanics at Columbia University in the period 1937-1945.

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