Contribution ID: **441** Type: **Oral Presentation**

Computational analysis of Single- and Two-Phase Flow with Poroelasticity

Wednesday, 2 June 2021 19:20 (15 minutes)

Coupled poromechanics involving single and multiphase flow during carbon sequestration, geothermal recovery, and waste disposal requires accurate numerical modeling of coupled processes in porous media. Over the past decade, iterative coupling schemes have been leveraged to model these coupled poroelastic problems. Specifically, the fixed stress scheme has been successfully used to solve poromechanics problems that involve both fluid and solid mechanics. In this work, two methods for implementation of the fixed stress scheme into the Sandia Sierra Multiphysics toolkit [1-3] are compared: one through an existing thermal/fluid mechanics module (ARIA) and the other through integration of the ARIA with the Sierra solid mechanics (SM) module. First, the fully coupled method of ARIA was compared with analytical solutions for poroelastic problems such as one-dimensional (Terzaghi), two-dimensional (Mandel), and three-dimensional (Cryer Sphere) problems. Model comparison shows that the fully coupled method in ARIA accurately match analytical solutions for all three problems. Second, the fixed stress schemes implemented in the Sierra SM were evaluated against the fully coupled numerical model. This work provides a unique comparison of the accuracy and computational demand for two implementations of the fixed stress scheme (ARIA and ARIA with SM) over a wide range of porous media properties. This research also shows that the fixed-stress scheme decreases early oscillations in pore pressure for first-order, linearly interpolated finite elements, versus the fully coupled model. Then, stability of the fixed stress scheme is further investigated by evaluating two different GMRES (generalized minimum residual method) solvers available in Sierra Multiphysics toolkit. Third, the fixed stress scheme is expanded into multi-phase flow problem where effective pore pressure is calculated in two different ways, including saturation weighted method and thermodynamic-based method. Through modeling of a water-air system, the accuracy of two-phase flow with the fixed stress scheme and calculation of effective pore pressure is evaluated. This work advances current single- and two-phase flow modeling techniques through a detailed description of fixed stress scheme implementation within multi-physics solvers.

SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525

Time Block Preference

Time Block C (18:00-21:00 CET)

References

References:
[1] SIERRA Multimechanics Module: Aria User Manual –Version 4.58, SIERRA Thermal/Fluid Development Team. SAND2020-11537, October 20, 2020.
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[3] SIERRA/Solid Mechanics 4.58 User's Guide, SIERRA Solid Mechanics Team, Computational Solid Mechanics and Structural Dynamics Department, Engineering Sciences Center. SAND2020-10045, October 20, 2020.

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Session Classification: MS12

Track Classification: (MS12) Advances in modeling and simulation of poromechanics