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The Global Inexact Newton Method as a Nonlinear Solver Framework in Multirate Iteratively Coupled Flow and Geomechanics Problems

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ABSTRACT

The coupling between subsurface flow and reservoir geomechanics plays a critical role in obtaining accurate results for models involving reservoir deformation, surface subsidence, well stability, sand production, waste deposition, hydraulic fracturing, CO2 sequestration, and hydrocarbon recovery [1]. Due to its physical nature, the geomechanics problem can cope with a coarser time step compared to the flow problem. This makes the multirate iterative coupling algorithm [1], the one in which the flow problem takes several "local" time steps within the same geomechanics coarser time step, a natural candidate in this setting. Due to complexities, nonlinearities, phase behavior, and the different partial differential equations required to describe a coupled system of poro-elasticity or poro-plasticity with multiphase flow, designing convergent and numerically optimized iterative coupling algorithms becomes a necessity. The global inexact Newton method, combined with the line search backtracking optimization algorithm along with heuristic forcing functions [2], can be efficiently employed in this context to optimize the underlying nonlinear solver for the different kinds of operators arising in such highly nonlinear iterative coupling settings. In this work, we establish efficiency gains obtained by employing the aforementioned method as a nonlinear solver framework to solve the nonlinear flow problem in multirate iteratively coupled flow and geomechanics schemes. For the fully implicit nonlinear two-phase flow problem (tested against the full SPE10 model), the run time was reduced by a factor of two, and the number of linear iterations was reduced by more than 50% compared to standard Newton methods. Motivated by these results, we incorporated this strategy as a nonlinear solver framework to solve the nonlinear flow problem in multirate iteratively coupled schemes (for the first time in literatue). This led to a scheme that reduced both the number of flow and mechanics linear iterations efficiently, and subsequently the overall CPU run time. Our numerical implementations in this work are built on top of the Integrated Parallel Accurate Reservoir Simulator (IPARS) [1]. [1] T. Almani: Efficient Algorithms for Flow Models Coupled with Geomechanics for Porous Media Applicatinos. Ph.D. thesis, The University of Texas at Austin. [2] Stanley C. Eisenstat and Homer F. Walker. Choosing The Forcing Terms in an Inexact Newton Method. SIAM JSC, 17:16–32, 1996.