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Constraint handling for gradient-based optimization of compositional reservoir flow

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Abstract

The development of adjoint gradient-based optimization techniques for general compositional flow problems is much more challenging than for oil-water problems due to the increased complexity of the code and the underlying physics. An additional challenge is the treatment of non smooth constraints, an example of which is a maximum gas rate specification in injection or production wells, when the control variables are well bottom-hole pressures. Constraint handling through lumping is a popular and efficient approach. It introduces a smooth function that approximates the maximum of the specified constraints over the entire model or on a well-by-well basis. However, it inevitably restricts the possible solution paths the optimizer may follow preventing it to converge to feasible solutions exhibiting higher optimal values. A simpler way to force feasibility, when the constraints are upper and lower bounds on output quantities, is to satisfy these constraints in the forward model. This heuristic treatment has been demonstrated to be more efficient than lumping and at the same time it obtained better feasible optimal solutions for several models of increased complexity. In this work a new formal constraint handling approach is presented. Necessary modifications of the nonlinear solver used at every timestep during the forward simulation are also discussed. All these constrained handling approaches are applied in a gradient-based optimization framework for exploring optimal CO2 injection strategies that enhance oil recovery for a realistic offshore field, the Norne field. The new approach recovers 4% more oil than the best of the optimal solutions obtain by its competitors.

Key words: Constraint-handling, production optimization, recovery-optimization, discrete adjoint.