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A scalable fully implicit framework for reservoir simulation on parallel computers

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Abstract

The modeling of multiphase fluid flow in porous medium is of interest in the field of reservoir simulation. The promising numerical methods in the literature are mostly based on the explicit or semi-implicit approach, which both have certain stability restrictions on the time step size. In this work, we introduce and study a scalable fully implicit solver for the simulation of two-phase flow in a porous medium with capillarity, gravity and compressibility, which is free from the limitations of the conventional methods. In the fully implicit framework, a mixed finite element method is applied to discretize the model equations for the spatial terms, and the implicit Backward Euler scheme with adaptive time stepping is used for the temporal integration. The resultant nonlinear system arising at each time step is solved in a monolithic way by using a Newton–Krylov type method. The corresponding linear system from the Newton iteration is large sparse, nonsymmetric and ill-conditioned, consequently posing a significant challenge to the fully implicit solver. To address this issue, the family of additive Schwarz preconditioners is taken into account to accelerate the convergence of the linear system, and thereby improves the robustness of the outer Newton method. Several test cases in one, two and three dimensions are used to validate the correctness of the scheme and examine the performance of the newly developed algorithm on parallel computers.

Keywords: Reservoir simulation, Fully implicit method, Schwarz preconditioner, Parallel computing

1. Introduction

Reservoir simulation models are used extensively by oil and gas industries to efficiently manage existing petroleum fields and to develop new oil and gas reservoirs [1, 9]. Although

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