Iterative Multiscale Finite Volume Method for Multiphase Flow in Heterogeneous Fractured Porous Media

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The Multiscale Finite Volume (MSFV) method is an efficient numerical method for the solution of heterogeneous elliptic and parabolic problems when approximate, but locally conservative solutions are required. Conservative solutions are important for the accurate solutions of transport problems. These requirements are common in oil reservoir simulations, where the classical numerical schemes become too expensive, since the size of the domain is much bigger than the resolution of the data provided by the geoscientists. It has been shown that the MSFV results match very well with those obtained from a classical numerical scheme at fine-scale. However, the level of error introduced by the method is problem dependent and is not bounded for highly anisotropic heterogeneous problems. To resolve this problem, a convergent iterative MSFV (i-MSFV) method is proposed. The i-MSFV method can be used as an iterative linear solver; however, its main advantage lies on the fact that a conservative solution field can be reconstructed after any iteration level. Therefore, it is shown that only few iterations are required in order to obtain good results even for very tough problems. Moreover, the i-MSFV iterations can be employed adaptively for a small sub-domain where the MSFV solutions are not acceptable.

In this work, the i-MSFV method is extended to include multiphase flow in heterogeneous fractured porous media. The n dimensional (nD) continuum medium (matrix) is loosely coupled with $(n-1)D$ fractures through a Darcy type coupling term. Local fracture functions are introduced to capture the fractures at the coarse scale accurately. Convergence study of the method is presented for many test cases. With the proposed loosely coupling strategy, it is very convenient to apply different type of physical modeling for the fracture and matrix media. This strategy also results in a much smaller system of equations to be solved for the matrix. In addition, independent grids are employed for the matrix and the fractures. Neither local grid refinement nor grid alinement are necessary in the proposed model. The numerical results show that the i-MSFV method is an efficient multiscale method for simulation of multiphase flow in heterogeneous fractured porous media.