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Numerical Simulation of Carbonate Matrix Acidizing Using Adaptive Enriched Galerkin Method

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Matrix acidizing is a stimulation technique that is extensively being employed by petroleum industry in carbonate reservoirs to improve permeability and enhance production [3]. The acidizing technique involves injecting acid to dissolve minerals in order to create long highly conductive channels known as wormholes. The wormhole formation is the optimal scenario in carbonate matrix acidizing. Intensive chemical reactions and pore structure changes mainly occur near the acid front. Predicting these wormholes and the performance of carbonate acidizing is challenging due to the multi-scale heterogeneous properties of carbonate reservoirs and complicated rock-acid chemical reactions.

One of the classical methods employed in the acid transport is the first-order finite volume method on static mesh. However, the numerical solution exhibits diffusive acid fronts and the method requires very fine mesh to resolve wormholes. Here we employ a two-scale continuum model proposed in [3] for the matrix acidizing problem. To simulate wormholes more accurately and efficiently,
we develop a new numerical simulator for acidizing using an adaptive enriched Galerkin finite element method (EG) [4,1,2]. The EG is formulated by enriching the conforming continuous Galerkin finite element spaces with piecewise constant functions. EG is a high-order method with less numerical dispersion and grid orientation effects than standard finite difference or finite volume methods.

The flow and transport equations are solved sequentially using EG. Entropy viscosity stabilization method [2] is used to prevent any non-physical acid concentration. Entropy residual is used as a posteriori error indicator to dynamically refine the mesh near the moving wormhole interface. Entropy residual stabilization is a very efficient technique to avoid spurious oscillations of the high-order EG method and capture sharp acid fronts for the reactive transport problem.

Several numerical examples are presented, which reproduce different dissolution patterns observed in previous laboratory experiments under different acid injection rates. One of the main advantages of the proposed adaptive EG method is that it reduces the number of degrees of freedom in the non-computationally-intensive areas, hence reduces the simulation runtime, while still capturing the wormhole formation.

References

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