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A field-scale streamline-based simulation of nanoparticle transport in porous media

Modeling nanoparticle (NP) transport in porous media is an important research topic in many subsurface engineering applications, such as enhanced oil recovery (EOR), fracture electromagnetic imaging and environmental remediation. An efficient field-scale simulation framework is critical for predicting NP performance and designing subsurface applications. In this work, an efficient streamline-based model is presented to simulate NP transport in field-scale subsurface systems by considering several engineered NP behaviors, such as retention, encapsulation, fluid viscosity change and rock permeability change.

The presented model implements the streamline-based simulation (SLS) approach and operator-splitting (OS) method in NP transport modeling. SLS has been proved to be quite efficient for solving transport in large and heterogeneous systems, where the pressure and velocity field are firstly solved on underlying grids using finite-difference (FD) method. After tracing streamlines, one-dimensional (1D) NP transport is solved independently along each streamline. OS offers the greater flexibility in selecting numerical schemes to solve different governing equations efficiently and accurately. For the NP transport model, explicit FD scheme, implicit FD scheme and adaptive numerical integration are used to solve advection, diffusion and retention terms, respectively.

The presented method is implemented in an in-house streamline-based simulator, it is verified against analytical solutions, a commercial FD reservoir simulator (ECLIPSE) and an academic FD colloid transport code (MNM1D). In the 1D homogeneous case, the effluent breakthrough curves (BTC) of the in-house simulator shows a good agreement with the analytical solution and MNM1D, respectively. In the 2D heterogeneous case, the BTC, cumulative production curve and concentration map of the in-house simulator all matchs well with the ECLIPSE solution. In addition, a synthetic 3D engineering design case, NP capsule gelation flooding, is performed to investigate the effect of displacing fluid and NP properties on displaced fluid production. Results show that the NP retention capacity and displacing fluid viscosity are the two dominant factors affecting the flooding performances. The CPU time of the synthetic case are also reported, where 8-30 minutes are required to simulate a 7-19 species system in a laptop.

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