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A Practical Scale-Up Workflow for Numerical Simulation of Post-CHOPS (Cold Heavy Oil Production with Sand) Solvent-Aided Processes

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Cold Heavy Oil Production with Sand (CHOPS) is widely used as a primary non-thermal production technique in thin heavy oil reservoirs. Development of the complex wormhole networks (i.e., high-permeability channels caused by sand production) renders the scalability of post-CHOPS solvent-aided processes to field applications challenging. It is widely accepted that configuration of wormhole networks and foamy oil flow are key characteristics pertinent to these processes.

First, a series of mechanistic compositional simulation models at the lab scale is constructed to model a cyclic solvent injection scheme (CSI). These models are calibrated against experimental measurements of solvent diffusion measured in porous media. Next, a set of detailed high-resolution (fine-scale) simulation models, where both matrix and high-permeability wormholes (modeled as fractal networks) are represented explicitly in the computational domain, is constructed to model how the solvent propagates away from the wormholes and into the bypassed matrix. Finally, a statistical scale-up procedure is developed to assign parameters of the equivalent dual-permeability model (e.g., dispersivities, shape factors) in accordance to the grid size and wormhole intensity within the grid block. The novelty of this scheme is that the bivariate distributions between effective dispersivities and wormhole intensity at the coarse scale are calibrated from detailed fine-scale simulations.

In the end, field-scale simulations are constructed using average petrophysical and fluid properties extracted from several existing CHOPS reservoirs. Wormhole development and the end state of CHOPS are modeled using the concept of critical pressure gradient. Multiple field injection scenarios (i.e., of different number of cycles and durations of the soaking period) are analyzed. As expected, extended soaking period is more beneficial in terms of ultimate oil recovery, but it also reduces the early production rate. Interestingly, when an economic limit (i.e., minimum oil producing rate) is imposed, the optimal soaking time is not necessarily the longest one. It depends on the trade-off between extracting additional oil recovery at late times versus producing at a higher rate at early times. Our results also support the strategy of injecting all the solvent in one single consolidated cycle, with an extended soaking period, rather than performing shorter consecutive cycles.

Field-scale flow simulations are often performed to approximate the reservoir response and to optimize operating strategies. However, grid block sizes in field-scale models are generally much larger than the wormhole scale, and numerical analysis is often performed by arbitrary adjustment of dispersivity. This work, however, offers a statistical scale-up workflow that facilitates the construction of coarse-scale dual-permeability models, whose shape factors, fracture spacing, fracture porosity, and effective dispersivities are assigned based on calibration against simulation results of detailed fine-scale wormhole network models. The proposed method serves as a starting point for formulating a systematic workflow that can be integrated with commercial reservoir simulators to effectively simulate solvent processes in wormhole networks that span over multiple scales.

References

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