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Modelling the transport of particulate suspensions and formation damage during the deep injection of carbon dioxide

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Abstract

Prediction of CO_2 injection performance in deep subsurface aquifers and reservoirs rely in part on the interplay and integration of mechanistic transport processes at the laboratory and field scales. Dynamics of solid particulate suspensions in permeable media is one of the three major factors leading to injection well blow-out, beside other impacts caused by precipitating mineral reactions and clay swelling. The invading supercritical CO_2 fluid can contain significant concentrations of particulate suspensions generated in-situ, during the operations of well completion. Suspended solids can plug the pores leading to significant formation damage and permeability reduction in the vicinity of the injector. As such, models which can predict wells injectivity decline are useful in the operations of planning, design, and maintenance related to carbon dioxide injection. In the current work, the internal cake build-up is modelled as a mass filtration process. In this study we developed a finite element based simulator to predict the injectivity decline of CO_2 injector on the laboratory scale considering single phase flow, and at the field scale where two-phase flow dynamics of water and CO_2 are of important concern. The numerical model solves implicitly a system of two or three coupled sets of finite element equations. In the single phase case, these equations are the global pressure and the particles convective-diffusive mass conservation equations, while in the more general two-phase flow settings the non-wetting phase (i.e. CO_2) saturation equation and the relative-permeability-saturation-capillary-pressure closure relationships are equally provided. Permeability reduction is modelled as a function of (i) porosity reduction, (ii) increased surface area, and (iii) increased tortuosity. The simulator provides a practical tool to study the well injectivity according to the thermo-physical properties of CO_2-particles mixture, the petrophysical properties of the host formation, the injection flow rate and the well completion. Results of the numerical experiments and parametric sensitivity analysis indicate well injectivity dependence on the fluid quality (i.e. concentration of particulate suspensions), initial permeability of the host formation, initial well damage, and the flow rate and/or the injection pressure. High particulate concentrations, a relatively low flow rate of injection (or low pressures of injection), and low permeability favour rapid injectivity loss as a function of time. Finally, we provide a demonstration test case supporting a suggestion to build-up the injectivity of the well periodically by alternating periods of high injection rates and well shutoff.

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