P02

Sensitivity Analysis of Modeling Reservoir Formation Damage by an Adjoin-state Two-phase Particulate Transport Simulator

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SUMMARY

Quantifying productivity/injectivity performance in highly heterogeneous carbonate reservoirs remains a challenge because of the interaction of many interdependent processes belonging to different scales. In particular, dynamics of particulate suspensions at the Darcy scale are intimately related to the competing mechanisms of hydrodynamic/colloidal release from pore surfaces, and blocking in pore bodies/throats. Additionally, within immiscible two-phase flows additional processes occur such as interphase mass transfer.

Abstract

Quantifying productivity/injectivity performance in highly heterogeneous carbonate reservoirs remains a challenge because of the interaction of many interdependent processes belonging to different scales. In particular, dynamics of particulate suspensions at the Darcy scale are intimately related to the competing mechanisms of hydrodynamic/colloidal release from pore surfaces, and blocking in pore bodies/throats. Additionally, within immiscible two-phase flows additional processes occur such as interphase mass transfer.

Predictive numerical modelling of these processes requires a careful selection of the model parameters, which are usually difficult to assess experimentally at different reservoir conditions. Model sensitivity to operational and rock fabric parameters are therefore often overlooked in the analysis of such complex numerical models relying on many coupled equations and highly parameterised pore-scale related processes. In this work we propose a set of frugal and therefore computationally cheap methods, to determine the most sensitive parameters in the framework of an existing two-phase flow formation damage simulator (Sbai and Azaroual, 2011). The objective of this research is to develop a discrete adjoint-state model from the forward model to guide the often-needed sensitivity analysis and demonstrating the feasibility and efficiency of the proposed approach.

Sensitivity indices are calculated for any function of model outputs with respect to any model inputs highlighting which parameters are most important to predictions. We conclude that the observed adjoint to forward runtime ratio does not exceed 10 at worst for highly nonlinear models. We demonstrate this behaviour on static reservoir models extracted from the SPE10 comparative solution project. In particular, it is shown that uncertainties in particulate transport rates dominate the remaining uncertainties in two-phase fluid flow properties for predicting the porosity and permeability reduction functions.

Figure 1 Example of simulation results after one month of injection in a five-spot well pattern. The figures show the distribution of deposited particles in pore surfaces for a (i) smooth (left) and (ii) sharp (right) heterogeneous mediums. In the first case particle deposition is dominated by wells hydraulic interactions, while in the second case the permeability controls this process.

References

- Sbai, M. A. and Azaroual M. (2011) Numerical modeling of formation damage by two-phase particulate transport processes during CO₂ injection in deep heterogenous porous media. *Advances in Water Resources*, **34**, 62-82.