Numerical Simulation of Oil Recovery By Polymer Injection Using COMSOL

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Abstract

Introduction: Oil extraction from porous subsurface reservoirs can be classified into three different stages, namely the primary, secondary and tertiary recovery. The latter one is also termed enhanced oil recovery (EOR). Within the primary recovery phase the natural drive energy already available in the reservoir is utilized to produce the oil. Natural energy includes rock and fluid expansion, water influx, solution drive, gas cap drive and gravity drainage. During the primary recovery period no further energy needs to be injected into the reservoir. Later, due to oil extraction the natural drive energy declines. To maintain production external energy sources, mainly water or gas are injected into the reservoir for the purpose of maintaining reservoir pressure and improving sweep efficiency. This phase is considered as secondary recovery. With increasing energy demand and high oil prices sophisticated tertiary recovery technologies are implemented to extract more oil from existing hydrocarbon reservoirs. Enhanced oil recovery consists of the injection of chemicals, heat or miscible gases which are in general not normally present in the reservoir. One of the chemical tertiary technologies which can significantly increase the oil recovery factor is termed polymer EOR. It involves the mixing of special polymers with the injection water to increase water viscosity and reduce water permeability during the flow through porous media. As a result the mobility of water is decreased, leading in a more efficient displacement process and a higher oil recovery factor. However, several physical and chemical processes accompany the flow of aqueous polymer solutions through the porous formation resulting in loss of polymer solution viscosity, hence, in lower oil recovery. Detailed understanding of these effects is crucial to successfully design polymer EOR projects. Use of COMSOL Multiphysics: In this paper we used COMSOL Multiphysics to model basic physico-chemical effects relevant in polymer EOR such as non-Newtonian rheology of the displacing phase, permeability reduction, retention and salinity effects. COMSOL's PDE Interfaces as well as Species Transport in Porous Media interface were used during the simulation. Results: Results for one possible oil recovery scenario are presented in Figure 1 to Figure 4. First only water is injected into the reservoir to displace the oil (Figure 1) while the polymer concentration is zero (Figure 2). Between 130 and 160 days a polymer slug is injected resulting in the formation of an oil bank which is displaced to the production side (Figure 3). Due to adsorption of the polymer to the rock aqueous solution viscosity is reduced, resulting in a decreased displacement efficiency and oil recovery (Figure 3 and 4). Conclusion: Due to its PDE Interface and Species Transport in Porous Media Interface COMSOL Multiphysics provides a flexible framework to implement physical and chemical mechanisms relevant to polymer EOR. Although commercial software for simulation of polymer EOR processes exists, it lacks the multi-physics capabilities of COMSOL. Underlying transport and auxiliary equations can be easily varied or extended and other

physics such as temperature or geo-mechanical effects integrated. This is an important aspect in research.

Figures used in the abstract

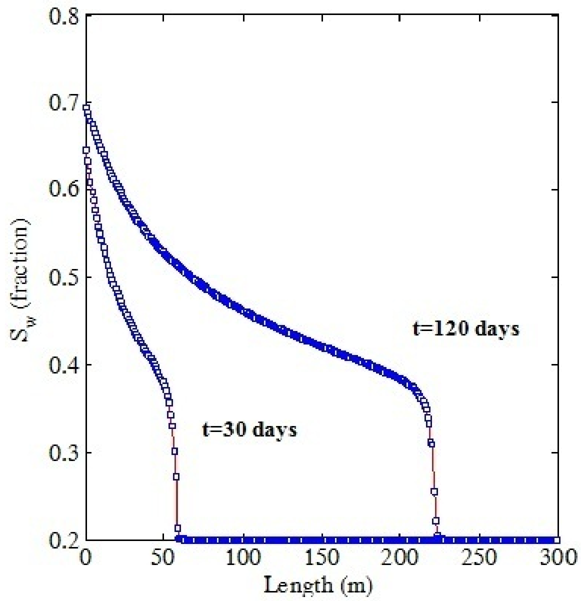

Figure 1: Water saturation after 30 and 120 days.

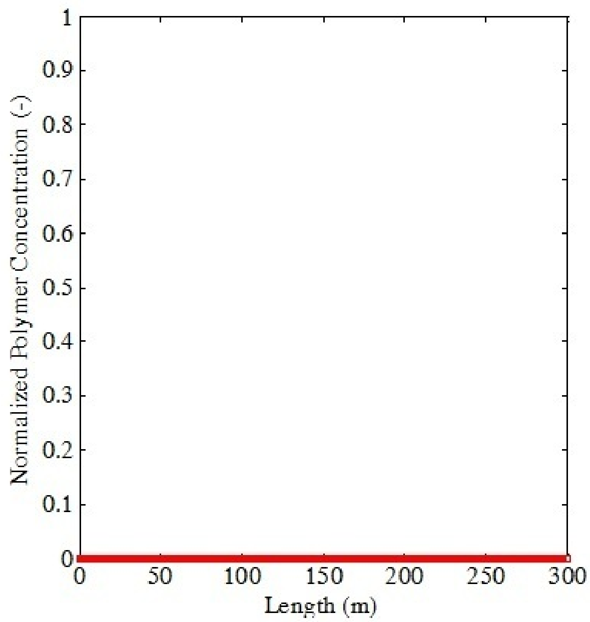

Figure 2: Polymer concentration during the first 130 days is zero.

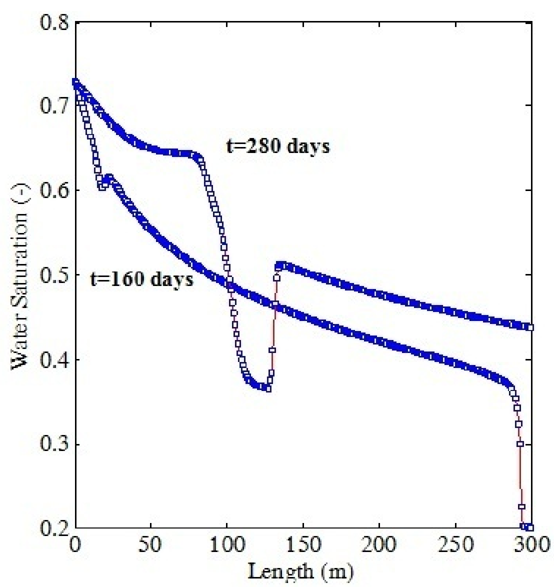

Figure 3: Water saturation after 160 and 280 days. Adding polymers to the injection water results in increased water viscosity and reduced water permeability, hence, in the formation of an additional oil bank and improved oil recovery. However, process efficiency is reduced due to polymer adsorption.

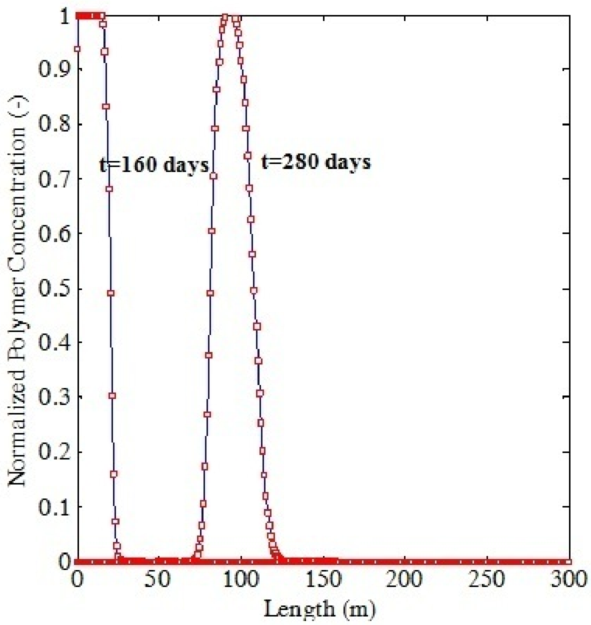

Figure 4: Normalized polymer concentration after 160 and 240 days. Polymer concentration is reduced due to adsorption of polymers from the aqueous phase to the rock surface.