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Numerical Simulation of Oil Recovery by Polymer Injection using COMSOL Multiphysics

J. Wegner[1], L. Ganzer[1]
[1]Clausthal University of Technology, Institute of Petroleum Engineering, Clausthal, Germany

Introduction: With increasing energy demand and high oil prices sophisticated enhanced oil recovery (EOR) technologies are implemented to extract more oil from existing hydrocarbon reservoirs. One of the chemical tertiary technologies is polymer EOR. The basic principle is sketched in Figure 1. It consists of mixing polymers to the injection water to increase water viscosity and reduce water permeability. Several physico-chemical processes accompany the flow of aqueous polymer solutions through the porous formation, such as:

- Permeability reduction
- Non - Newtonian rheology
- Adsorption
- Salinity of the injection water

The goal of this work is the COMSOL implementation of a numerical model capable to simulate the recovery of oil by means of polymer EOR taking into account basic physico - chemical effects. The model will be the basis for further and more detailed investigations.

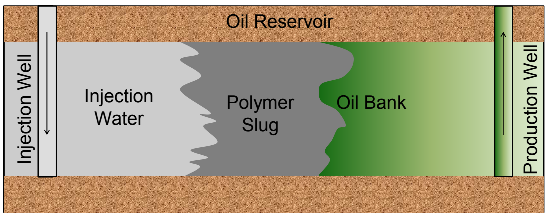

Figure 1: Basic principle of polymer EOR.

Computational Methods: The flow of an oleic and aqueous phase in porous media is described by the mass conservation for each phase (1) and (2). Polymer and salt are convected with the bulk Darcy velocity of the aqueous phase. For both, salt and polymer, a transport equation is required (Equations (3) and (4)).

$$\frac{\partial(\phi S_o)}{\partial t} = \nabla\cdot\left(\frac{k_o}{\mu_o}\nabla p_o\right) + \tilde{q}_o \qquad (1)$$

$$\frac{\partial(\phi S_a)}{\partial t} = \nabla\cdot\left(\frac{k_a}{\mu_a}\nabla p_a\right) + \tilde{q}_a \qquad (2)$$

$$\frac{\partial(\phi S_a C_p)}{\partial t} + \frac{\partial(\rho_r(1-\phi)C_{pad})}{\partial t} = \nabla\cdot\left(C_p\frac{k_a}{\mu_a}\nabla p_a\right) + \tilde{q}_a C_{pw} \qquad (3)$$

$$\frac{\partial(\phi S_a C_s)}{\partial t} = \nabla\cdot\left(C_s\frac{k_a}{\mu_a}\nabla p_a\right) + \tilde{q}_a C_{sw} \qquad (4)$$

Due to adsorption of polymer on the rock-fluid interface, physical parameters such as the rock permeability change. In addition to adsorption, non-Newtonian rheology and salinity effects have an impact on the aqueous phase viscosity. Therefore, additional constitutive equations are required. The system of equations is solved using COMSOL's PDE and Species Transport in Porous Media Interface.

Results: In order to validate the implementation of the polymer flood model presented here, a generic simulation model was set-up. The results obtained with COMSOL are compared to the results obtained using the commercial finite-difference simulator ECLIPSE© Blackoil by Schlumberger [1] (Figure 2 through 5). The injection Scheme is presented in Table 1.

Table 1: Polymer injection scheme.

Time [days]	Injection Rate, [m³/day]	Salt Inj. Conc., [kg/m³]	Polymer Inj. Conc., [kg/m³]
0 - 100	10	5	0
100 - 200	10	5	1
200 - 1000	10	5	0

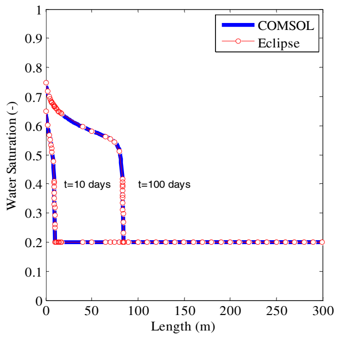

Figure 2: Water saturation after 10 and 100 days

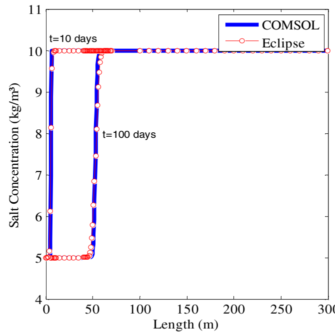

Figure 3: Salt concentration after 10 and 100 days

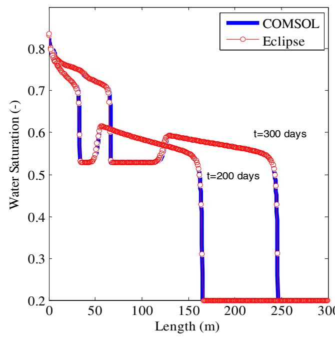

Figure 4: Oil bank after 200 and 300 days

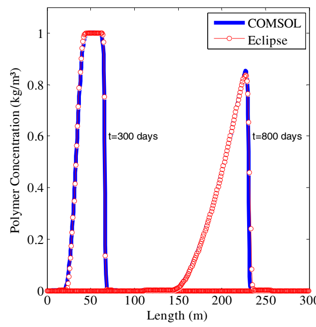

Figure 5: Polymer concentration after 300 and 800 days

Conclusions: Basic physico-chemical effects relevant to polymer EOR can be modeled in COMSOL. The presented results show good agreement compared to the reservoir simulator ECLIPSE by Schlumberger indicating a successful implementation.

References:

1. ECLIPSE© Blackoil Simulator, Technical Description 2011.1., Schlumberger.