Numerical aspects of special component modelling in enhanced oil recovery

Supervisor: Johan Romate (Shell/TUD)

Problem background
In petroleum reservoir engineering various techniques are used to enhance the oil recovery from a reservoir. In waterflooding water is injected in one or more places (injection wells) in a reservoir under high enough pressure for the oil in the reservoir to be moved by the injected water towards the producing wells of the reservoir (oil displacement). To further enhance the recovery further substances may be added in small quantities to the injection water. One example is the addition of polymer. The polymer may be tracked by a separate transport equation for the polymer concentration and coupled to the porous media multiphase flow model. Other special components may be modelled in a similar way.

Here we consider a water injection with one or more special components added. We assume oil and water to be incompressible and there is no mass transfer between the phases. The two-phase flow model of incompressible fluid flow through a porous medium we consider is given by the transport equations for the phase masses for oil and water (w=water, o=oil),

$$\frac{\partial}{\partial t}\left(\phi\rho_o S_o\right) + \nabla\cdot\left(\phi\rho_o \mathbf{v}_o\right) = 0,$$

$$\frac{\partial}{\partial t}\left(\phi\rho_w S_w\right) + \nabla\cdot\left(\phi\rho_w \mathbf{v}_w\right) = 0,$$

and Darcy's equations,

$$\mathbf{q}_o = -\frac{kk_{ro}}{\mu_o}\nabla dp_o = -\lambda_o \nabla p_o,$$

$$\mathbf{q}_w = -\frac{kk_{rw}}{\mu_w}\nabla dp_w = -\lambda_w \nabla p_w,$$

These equations are written in terms of the fluid phase pressures (p_o and p_w) and the fluid phase volume fractions (the saturations S_o and S_w), which need to be solved from these equations given appropriate data. The actual velocities $\mathbf{v}_i$ are related to the Darcy (or superficial) velocities $\mathbf{q}_i$ by $\mathbf{q}_i = \phi\mathbf{v}_i$. Additionally, we require that the saturations add to one:

$$S_o + S_w = 1.$$

Due to surface tension the oil and water pressures are not equal. The difference between the two pressures is the capillary pressure, p_c:

$$p_c = p_o - p_w.$$

Furthermore, the reservoir is taken horizontal: the effect of gravity is neglected.

For a special component c we add a transport equation including convection, diffusion, dispersion and source terms, which needs to be solved in combination with the (multiphase) flow equations above. For example,

$$\frac{\partial}{\partial t}\left(\phi\rho_w S_w c\right) + \nabla\cdot\left(\rho_w c\mathbf{q}_w\right) = \nabla\cdot\left(\phi\rho_w S_w (D_{diff} + D_{disp})\right)\nabla c + q.$$

Assignment

In this assignment a numerical model for the combined flow and special component transport system is developed in one and two space dimensions. Aspects to be investigated are the coupling between the flow and the transport part of the equation system, the order of accuracy of the numerical model for the transport equations (high-resolution methods), and the terms in the transport equations for modelling the various physical phenomena. The numerical model should be robust, stable, and efficient. The model outcome is meant to be compared to the results obtained from an existing reservoir simulator.

Literature

[1] K. Aziz; A. Settari: *Petroleum Reservoir Simulation* Applied Science Publishers, London, 1979.