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## **The Displacement of Oil by Polymer Slugs Considering Adsorption Effects**

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### **Abstract**

Oil displacement by injection of chemical solutions is a widespread Enhanced Oil Recovery method. Analytical models for one-dimensional displacement of oil by water with chemical components have been developed since the 1960's. This problem involves complex physical-chemical processes of interphase mass transfer, phase transitions and transport properties changes. The continuous injection of this kind of fluid would be very expensive, so, the injection of chemical slugs is an attractive alternative to improve the recovery of mature oil fields. The continuous injection of chemical solutions is a Riemann problem, easily solved by the introduction of a self-similar variable. Nevertheless, the slug injection is not self-similar, and the problem becomes much more complex from the mathematical point of view. This paper presents the analytical solution of chemical slug injection in an oil reservoir. A flow potential associated with the conservation of the aqueous phase is introduced as a new independent variable instead of time. This change of variables allows the system splitting into one equation (lifting equation) and a thermodynamic system (auxiliary system). The number of auxiliary equations is less than the number of equations in the compositional model by one. In this paper different adsorption isotherms were analyzed. The transport equation solution, or lifting problem solution involves interaction between waves of different families and allows the design of slug sizes in order to obtain the maximum efficiency of this process. Another important application of these solutions is the prediction of chemical flooding regardless of the transport properties (relative permeabilities and viscosities). If the mobility ratio is close to one, this model may be applied in the development of streamlines simulators.

### **Introduction**

Enhanced Oil Recovery (EOR) methods are applied to increase the recovery from reservoirs whenever a conventional method is not attractive. Among different EOR methods the injection of chemical solutions plays an important role in mature field additional recovery. The chemical methods of enhanced oil recovery include injection of aqueous solutions of several chemical components (polymers, surfactants, salts, etc.) that affect the flow of each phase in porous media (Lake, 1989). Polymer flood consists of adding polymer to the injected water to decrease its mobility. This technique improves reservoir sweep and reduces the amount of injection fluid necessary to recover a given amount of oil. Low concentrations of water-soluble polymers added to the injection water increase the injected fluid viscosity. Displacement of oil by these fluids involves complex physico-chemical processes of interphase mass transfer, phase transitions and transport properties changes. These processes can be divided into two main categories: thermodynamical and hydrodynamical ones. They occur simultaneously during the displacement, and are coupled in the modern mathematical models of EOR.

One-dimensional displacement of oil by multicomponent chemical solutions taking into account adsorption is described by a hyperbolic system of conservation laws. These systems have been studied since the end of 50's. Fayers and Perrine (1959) were pioneers; they analyzed a  $2 \times 2$  hyperbolic system considering continuous polymer injection. The problem of one dimensional isothermal multicomponent chromatography with local phase equilibrium without diffusion effects was solved considering the Langmuir's adsorption isotherm. The results showed the fitting between the thermodynamic system and the quasilinear equation theory (Rhee et al, 1970). Entov and Polishchuk (1975) studied the effects of adsorption and diffusion in filtration process through experimental data.

Exact analytical solutions were obtained for continuous chemical flooding with one dissolved component (Fayers, 1962; de Nevers, 1964; Claridge and Bondor, 1974), with two dissolved components (Braginskaya and Entov, 1980) and by any arbitrary number of components (Johansen and Winther, 1989; Johansen et al., 1989; Dahl et al., 1992). Helfferich (1981) presented an approximate model to describe the continuous oil displacement by multicomponent solutions. Capillary, dispersion and diffusion effects on the Riemann problem solution were studied by Alishayeva e Entov (1983) e Bedrikovetsky