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Constructing Three-Phase Capillary Pressure Functions by Parameter Matching Using a Modified Ensemble Kalman Filter

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Abstract. Usually extended two-phase capillary pressures are used in three-phase simulations, because three-phase capillary pressures are not possible or hard to measure. In this work three-phase capillary pressure surfaces are created by at pore network model. The input parameters to this network model are found by matching two-phase capillary pressure curves. This matching is done with a slightly modified EnKF routine. Tables with three-phase capillary pressures are created and used as input to flow simulations.

AMS subject classifications: 76T30, 37M05, 37N10, 35Q80, 60G35, 62M20, 62F15, 45Q05

Key words: Ensemble Kalman Filter (EnKF), three-phase porous media flow, capillary pressure, parameter matching.

1 Introduction

When starting production from an oil reservoir the pressure drops, and this pressure needs to be replaced if you want high oil recovery. Injection of water is the most common way to maintain the pressure, but also injection of gas is used.

In recent years it has been shown that a water-alternating-gas (WAG) scenario, where short slugs of gas and water are injected in a sequence, results in lower residual oil, less trapped oil in the reservoir, than if you inject only water or only gas. Skauge and Stensen reported an increased oil recovery from WAG of five to ten percent of the initial oil in place [1].

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The combination of gas and water gives many favorable effects [2, 3]. Gas results in better microscopic displacement; less oil left in the pores of the gas swept areas when compared to water swept areas. The zones swept with both gas and water may have even lower trapped oil saturation [4–7].

The water is controlling the mobility of gas and consequently the stability of the displacement front i.e. the transition zone between injected fluid and oil. The result is better macroscopic displacement of the oil. Without water present the gas would sweep a much smaller volume, because the gas would then zoom through at the top of the reservoir or through zones with high pore connectivity, high permeability. There would be more oil left in the reservoir and earlier breakthrough of gas in the producers.

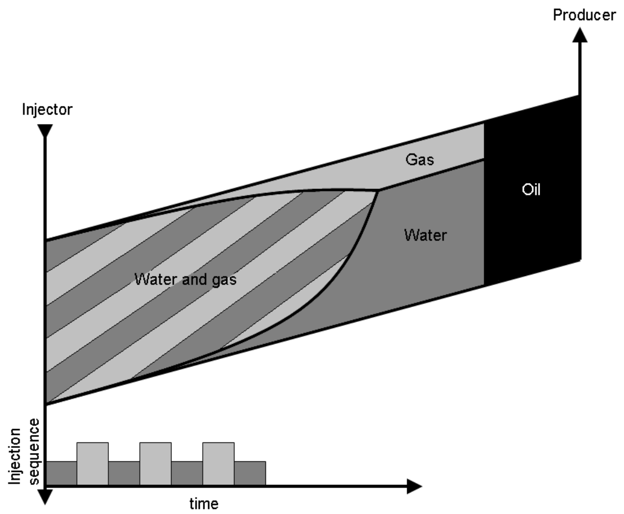

Figure 1: Schematic sketch of WAG injection (Adapted from NPD [5]).

In thick homogeneous reservoirs the main advantage of WAG is the improved vertical sweep due to gravity segregation of water and gas. The water sinks to the bottom and the gas rises to the top of the reservoir. This effect can be seen in Fig. 1. At the top of the reservoir we get two-phase flow of gas and oil, and near the bottom we get two-phase flow of water and oil. In parts of the reservoir, especially close to the injector we get three-phase flow of gas, water and oil. Gas, water and oil are then flowing simultaneously and interacting in the reservoir.

In homogeneous reservoirs the gas and water may segregate rapidly and the three-phase zone is then located close to the injector. The region with three-phase flow can in many cases extend to a considerable part of the reservoir. More heterogeneous reservoirs may have a slower segregation of the fluids. Lower mobility of gas and water in the three-phase zone also delays the segregation process [6, 7].

The influence of capillary pressure is often neglected in complex three-phase processes like immiscible WAG. There is very little experimental data on three phase capillary pressure available. In Kalaydjian [8], three-phase capillary pressure was measured