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Title A New Model for Three-Phase Relative Permeabilities Based on a Fractal Representation of the Porous Medium
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Abstract

Three-phase flow in a porous medium is usually described by the Stone model (1970). This model is based on two-phase data and relies on empirical correlations. It is valid only under strong water wettability and recognized as having poor predictability.

The objective of the present study is to develop a mathematical model for three-phase flow avoiding any empirical correlations. In this paper, only strong water-wet and spreading conditions are considered. However the model could be relatively easily extended to oil-wet or even mixed-wet conditions.

The model is based on a physically relevant description of phase distribution and flow mechanisms at the pore scale. The porous medium is described as a set of fractal pores, whose linear fractal dimension and size distributions are derived from a mercury intrusion capillary pressure curve. The fluids are allowed to flow together in the same fractal pore, gas in the center, water in the vicinity of the walls and oil as an intermediate phase. The relative permeabilities are evaluated by calculating the flow of each fluid applying Poiseuille's law.

The model results are compared to relative permeabilities obtained by history matching of gas injection experiments. The same experiments are also simulated using Stone's model and laboratory measured two-phase data.

Introduction

Many attempts to describe multiphase flow behavior in oil reservoirs have addressed the problem of evaluating the relative permeability of each phase in a saturation range corresponding to the one found in the reservoir. This objective can be attained by two different ways: experiments and modeling.

Experimental determination of three-phase relative permeabilities is not a straightforward task. In fact, no direct method exists to measure relative permeabilities during a displacement, especially when all three phases are mobile. On the other hand, the problem is simplified with experiments where one of the three phases is immobile (at its irreducible saturation).

An easier way to obtain directly relative permeability values is the steady-state method. However the use of these relative permeabilities for the simulation of a displacement is questionable.

There have been several attempts to model three-phase relative permeabilities. Models based on a schematic description of the porous medium as a bundle of cylindrical capillaries have not been validated mainly due to lack of experimental results. Moreover the usually made

assumption that the more wetting fluid occupies the smallest pores and the less wetting the largest ones does not take into account complex fluid-fluid interactions encountered in three-phase flow.

Currently, three approaches are widely used to treat three- phase flow problems:

- use of steady-state experimental data for displacement simulations
- use of two-phase data to calculate three-phase parameters by the intermediate of a model such as the Stone's model.
- use of empirical correlations between relative permeabilities and saturations : the well-known power-laws in which the coefficients and exponents are fitting parameters.

The aim of the present paper is to evaluate experimentally relative permeability values corresponding to the displacement of oil and water by gas injection in a porous medium and to propose a model to calculate them based on a relevant physics but simple enough to be easily implemented in a reservoir simulator. The porous medium is described as a bundle of capillaries with their diameter following a power law. The cross-section of this object is fractal and its linear fractal dimension is found from the capillary pressure curve.