Unsteady Relative Permeability Measurement Considering Capillary Pressure and Saturation Profiles from Magnetic Resonance Imaging

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ABSTRACT

The continuous improvement of relative permeability determination is enabled by the evolving experimental imaging techniques due to its essential role in reservoir prediction and various assumptions in the existing methods. Capillary pressure is an integral part of any immiscible multiphase flow and fluid distribution, but it is not properly accounted for in the conventional relative permeability measurements due to analytical difficulty with the Johnson, Bossler, and Neumann (JBN) method or its availability from the same core sample in the history matching method. With the aid of saturation monitoring using magnetic resonance imaging (MRI) this study attempted to utilize the capillary pressure obtained from the preparatory oil flood step to the relative permeability estimation from the subsequent step of water flood. The core flood experiments were conducted in an Oxford GeoSpec12 (~0.3T) imager/spectrometer to monitor the oil saturation profiles. The commonly-used unsteady state experiments for relative permeability include two steps: oil flood to establish irreducible water saturation, and water flood to collect the production and pressure history for calculation. In this study, the saturation profiles were obtained at the end of the oil flood from which the capillary pressure was estimated by analysis of the capillary end effect enhanced by maintaining water contact at the core outlet surface. The measured capillary pressure was used as further input in the history matching for relative permeability with saturation profiles in addition to production and pressure history of the water flood step. The displacement experiments were performed on Berea sandstone and Indiana limestone core plug samples. It is found that, for the strongly water-wet Berea core, the capillary end effect was substantial and the capillary pressure can be obtained and input for relative permeability determination; for the limestone core, the capillary end effect was not very obvious and the capillary pressure may be neglected in history matching for the relative permeability without appreciable loss of accuracy. A suite of advanced NMR/MRI measurements (e.g. T2, spatial T2, 2D and 3D image) was conducted when permitted during the experiment to better correlate the core properties such as heterogeneity and wettability with relative permeability features.