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Uncertainty Assessment of Interpolation-Based Three Phase Relative Permeability Models

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A major element affecting uncertainty associated with prediction of three-phase flow in reservoirs is the parameterization of relative permeability. The latter are typically obtained through interpolation of two phase relative permeability data because of intrinsic difficulties related to direct measurements. Here, we discuss and analyze the saturation history dependency of water, oil and gas relative permeabilities and distinguish key features of three- and two- phase flow configurations. We start by investigating the advantages and limitations of several methodologies available in the literature and widely adopted in three-phase flow simulation. This analysis is performed by comparing model outcomes against experimental data published in the literature. The results provided by considering Corey-type equations as input to the aforesaid models is compared against the use of linear interpolation of two-phase measurements from oil-water and oil-gas environment. Our results show that available models typically fail to reproduce the set of experimental results ever the full range of saturations. This analysis suggests that not only saturation history but also wettability, residual oil and trapping behavior of oil during drainage and imbibition are key elements distinguishing between the physics of two- and three-phase settings. These effects should be taken in account to predict three-phase relative permeability.

We then propose an alternative formulation to compute oil relative permability under three-phase conditions. Our model takes into account (i) the dependence of three-phase oil relative permeability on the saturation path, and (ii) the effect of wettability observed for three-phase systems. The model is based on a sigmoid-type interpolation of the oil relative permeability-saturation data in a two-phase oil-water system. Three-phase oil relative permeability is then computed through an additional interpolation between the oil-water effective sigmoid curve and the oil-gas two-phase data. Model results are compared with experimental data for secondary water injection and primary gas injection. Sensitivity of the model outcome to the sigmoid interpolation parameters is considered through an uncertainty quantification study.

Keywords: oil relative permeability, WAG, cycle dependency, trapped oil.