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A theoretical analysis of the nonlinear behaviors in the measurements for two-phase flow in low-permeability core considering the capillary effects

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In recent years, the flow behaviors in low-permeability media have received much attention. Some experimental measurements indicate that single-phase flow in the low-permeability core seems to present the nonlinear behaviors rather than obeying the Darcy's law. However, there are different opinions on the explanation of the experimental measurements. For two-phase flow, some scholars pointed out that the capillary pressure (Jamin effect) is can cause the nonlinear seepage behavior. However, there is no corresponding mathematical model to describe it.

When two-phase fluid flows into the non-capillary force container from the core sample containing capillary force, the phase saturations at the outlet end of the core increase significantly compared with the rest of the area. This phenomenon was called as the capillary end effect. Considering capillary end effect, Yao et al. proposed a two-phase flow well model for low permeability gas reservoirs considering capillary end effect.

Considering the strong capillary pressure contrast between matrix and fracture in low-permeability reservoirs, Wang et.al pointed out that, there are three flow patterns for the two-phase flow across the matrix-fracture interface: (1) When the pressure difference between matrix and fracture can overcome the capillary end effect, both two-phase fluids flow from matrix to fracture and saturation gradient and the non-wetting phase pressure gradient diverged near the matrix interface; (2) When the pressure difference between matrix and fracture cannot overcome the capillary end effect, only non-wetting phase flows from matrix to fracture; (3) Both two phases flow from fracture to matrix, wetting phase pressure is discontinuous across matrix - fracture interface.

In this article, the two-phase flow behaviors in the low-permeability core experiment are analyzed. The dramatic capillary pressure difference between the core and the vessel will lead to wetting phase pressure discontinuity at the core inlet and the divergence of saturation gradient and non-wetting phase pressure gradient at the core outlet. Under the condition of that the two-phase flow in the low-permeability core satisfies the generalized Darcy's law, a rigorous mathematical analysis is presented that the dramatic capillary pressure difference between the core and the vessel can cause the pressure difference-flow rate curve to be nonlinear.

Low permeability reservoirs are usually highly heterogeneous and there are many natural fractures in the reservoirs. The multi-scale effects of flow on the matrix-natural fracture interface result in strong capillary heterogeneity. So even though the flow in the matrix and natural fractures satisfies the generalized Darcy law, the two-phase flow in low-permeability reservoirs may show the nonlinear behaviors at macroscopic reservoirs scales.

Capillary end effect can cause great error to the steady-state relative permeability measurement experiment data. Through numerical simulation, Gupta et al. (2016) proposed an intercept method to correct the steady-state relative permeability measurement data considering capillary end effect. Andersen et al. (2020) gave a mathematical proof of Gupta et al.'s intercept method in the condition of the specific capillary and relative permeability curves. In this article, a rigorous mathematical proof of this method is proposed.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

[1] Wang, X. H., Quintard, M., & Darche, G. (2006). Adaptive mesh refinement for one-dimensional three-phase flow with phase change in porous media. Numerical Heat Transfer, Part B: Fundamentals, 50 (3), 231-268.
[2] Ding, Y. X., Shi, A. F., Luo, H. S., & Wang, X. H. (2016). Adaptive mesh refinement for non-isothermal multiphase flows in heterogeneous porous media comprising different rock types with tensor permeability. Numerical Heat Transfer, Part A: Applications, 69 (1), 31-50.
[3] Yao, Y. M., Shi, A. F., Wang, X. H., & Liu, Z. F. (2019). A numerical well model considering capillary end effect for the low-permeability gas reservoir. Oil & Gas Science and Technology–Revue d'IFP Energies nouvelles, 74, 87.
[4] Xiao-Wang, H., Li, L., Wang, M., Liu, Z. F., & Shi, A. F. (2020). A discrete fracture model for two-phase flow involving the capillary pressure discontinuities in fractured porous media. Advances in Water Resources, 103607.
[5] Gupta, R., & Maloney, D. R. (2016). Intercept method–A novel technique to correct steady-state relative permeability data for capillary end effects. SPE Reservoir Evaluation & Engineering, 19, 316-330.
[6] Andersen, Pål & Zhou, Y. (2020). Steady state relative permeability experiments with capillary end effects: Analytical Solutions including Derivation of the Intercept Method. Journal of Petroleum Science and Engineering. 10.1016/j.petrol.2020.107249.

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