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Description of the benchmark study COMPS-TEST-A

This benchmark study of miscible displacement of oil by hydrocarbon gas is considered in the article [1]. The problem statement is similar to one of the studies considered in the book [2].

We consider a simplified model of hydrocarbon gas injection into an oil reservoir. We simulate a one-dimensional flow in a homogeneous porous medium in the region $X\in[0;L]$, where X is the linear space coordinate. At the initial time, t=0, the porous medium is saturated with a hydrocarbon mixture of given composition. The initial reservoir fluid consists of four components: methane (C_1), propane (C_3), hexane (C_6), and hexadecane (C_{16}). At the initial time, t=0, the uniform distributions of pressure, P=137.5 bar, the temperature, T=93°C, and the fluid composition $\mathbf{z}=\{z_{(1)},\ldots,z_{(4)}\}=\{0.2, 0.0, 0.4, 0.4\}$ are imposed. Under these conditions, the hydrocarbon mixture is in the single-phase state of oil, i.e. the gas saturation is 0 ($s_g = 0$) and the oil saturation is 1 ($s_o = 1$). At t=0, a hydrocarbon gas, containing 90% of methane and 10% of propane, i.e. the gas of the following composition: $\mathbf{z}=\{0.9, 0.1, 0.0, 0.0\}$, begins to be injected through the boundary X=0 with the constant volume rate Q. The initial pressure of P=137.5 bar is kept constant at the open boundary $X=L$. The gas injection leads to the miscible displacement of oil from X=0 to $X=L$. We simulate the flow over 100 days of injection. The injection is simulated with a point source of hydrocarbon gas placed at X=0.

The formulated problem statement is the self-similar Riemann problem, because the flow parameters depend only on the variable $\xi = X\phi/Qt$ [2]. We use the following parameters in the simulation: the porosity is $\phi = 0.2$, the permeability is $K=2\cdot10^3$ mD, L=200 m and $Q = 0.2$ m/day. The relative permeability curves are given by the quadratic functions: $K_{rg} = s_g^2$, $K_{rog} = (1-s_g)^2$. We account for the realistic parameters of the vapor-liquid equilibria, phase transitions, volume changes, and other parameters of the non-ideal mixture by employing the Soave-Redlich-Kwong equation of state and the LBC correlation for the gas an oil viscosities.

The specified value of permeability K is so high ($K\to\infty$) that the pressure P weakly deviates from its initial value. Therefore, the influence of the changes in P on the physical and chemical parameters of hydrocarbons can be neglected. In this asymptotic case, the solution to the problem consists of a sequence of the displacement fronts (shocks), the Riemann waves (rarefactions), and the regions of constant state propagating from the boundary X=0 into the region X>0. The pressure changes, although they are rather small, are taken into account by the simulator.

The simulation results are presented in figures 1 and 2. The sequence of waves $S_4 - S_3RS_2 - S_1$ propagates from the boundary $X = 0$ into the region $X > 0$, where the symbols S, R and "–" denote the shocks, rarefactions and regions of constant state, respectively. The shock waves S are numbered in the direction of decreasing of the self-similar coordinate ξ. The fastest shock is S_1 and the slowest shock is S_4. The shock S_2 is "fuzzed" due to the influence of numerical dispersion. The shown distributions are in qualitative agreement with [2], although some quantitative discrepancies exist. The curves shown in figures 1 and 2 are obtained by post-processing the simulation result at t=100 days and changing the variable X to $\xi = X\phi/Qt$.

References

[1] Afanasyev A.A., Vedeneeva E.A. Investigation of the efficiency of gas and water injection into a petroleum reservoir // Fluid Dynamics 2020. In press.

[2] Orr F.M. Theory of gas injection processes. Holte, Denmark: Tie-Line Publications, 2007. 381 p. Chapter 6. Four-Component Displacements → Section 6.3. Systems with Variable K-values.

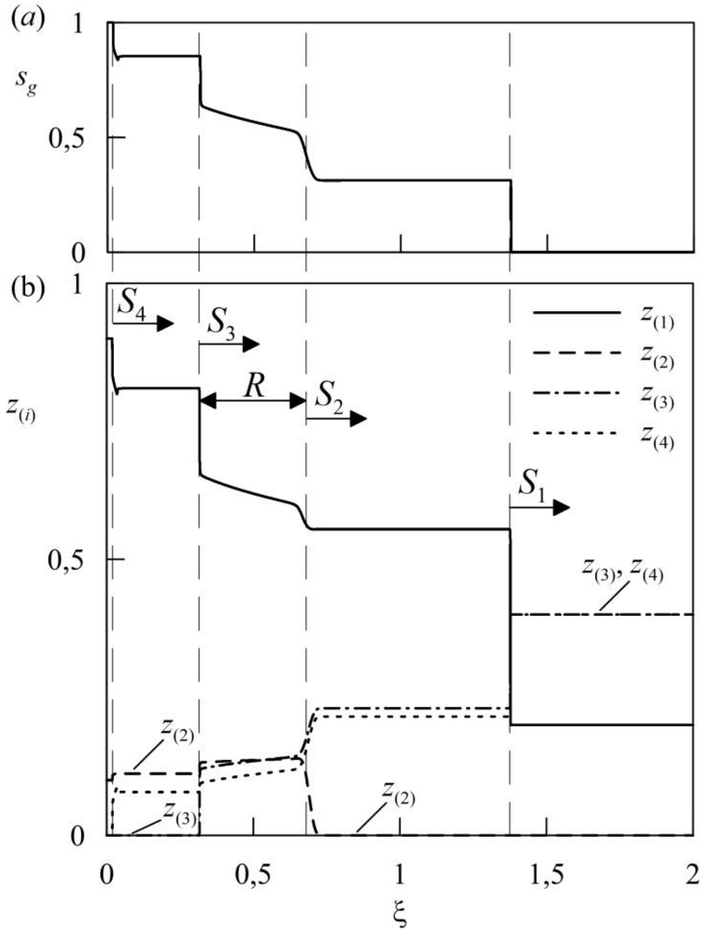

Fig. 1. The simulated gas saturation s_g (a) and the total molar concentrations $z_{(i)}$ (b) against the self-similar variable ξ .

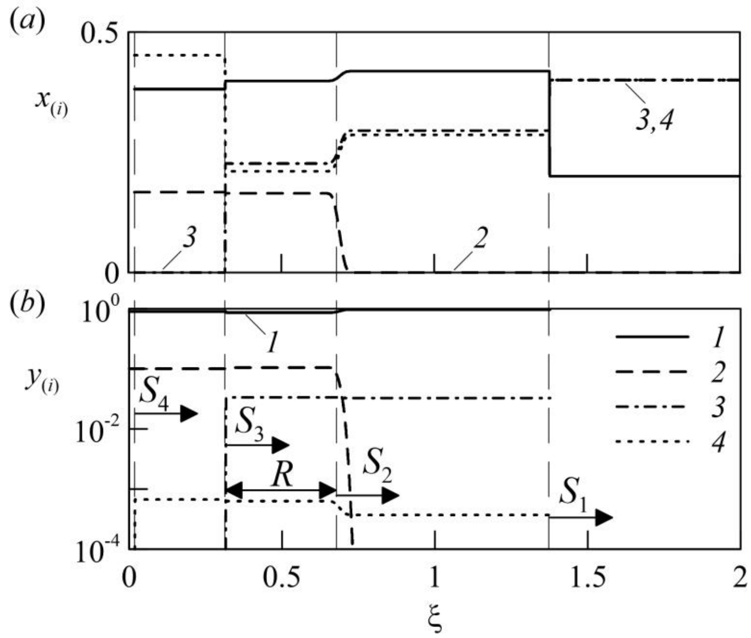

Fig. 2. The simulated compositions of oil (a) and gas (b) against the self-similar variable ($x_{(i)}$ and $y_{(i)}$, curves i=*1–4*, respectively).