Construction of traveling wave type solutions for filtration equations in mathematical modeling of oil and gas production

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The work is devoted to the construction of self-similar solutions of the "travelling wave" type of the equations of two-component filtration of solutions, accompanied by phase transitions. A model is considered that is widely used to solve the problems of predicting the development of oil and gas reservoirs. Within this model, two-component isothermal filtration is described by a system of non-linear partial differential equations, the solutions of which are characterized by the presence of discontinuities in component concentrations. It is assumed that the pressure is continuous, because filtration rates are small enough and the pressure has time to be established. If no particular assumptions are made about the properties of fluids (Amago's law, incompressibility of fluids, etc.), then in this general case the nonlinear equations of two-component filtration cannot be reduced to hyperbolic, parabolic, and elliptic ones. The study of multicomponent filtration, accompanied by phase transitions, in the general formulation is possible only with the involvement of mathematical modeling methods.

A model of two-component filtration with phase transitions is considered, which is widely used to solve problems of predicting the development of oil and gas reservoirs [1] - [3]. It is assumed that the filtration rates are low, and the mass transfer occurs quite intensively, so that phase equilibrium has time to be established in each elementary volume. Depending on the temperature and pressure conditions, a two-component mixture can be either in a single-phase state or in a two-phase state. In the second case, we will conditionally consider the denser phase to be liquid and mark the quantities corresponding to it with the index L, and the less dense phase, the gas phase and mark it with the index G.

Nonlinear equations of two-component filtration demonstrate the properties of hyperbolic, parabolic and elliptic types of equations. The solutions of the system of equations describing filtration are characterized by the presence of strong and weak concentration discontinuities propagating at a finite speed. The task becomes more complicated if phase transitions are present. Unpredictable changes in composition and phase saturation are one of the problems in the development of "carbonated" oil and gas condensate deposits. Self-similar solutions are of great interest both for testing numerical algorithms [2] and for studying complex filtration flows. In underground hydrodynamics, self-similar solutions of filtration equations obtained for incompressible phases without phase transitions are well known. Such solutions are used to study the processes of oil displacement by water or compressed gas. However, phase compressibility often plays a significant role. In this work, no particular assumptions about the properties of fluids are made, i.e. fluids can be either compressible or incompressible, and phase transitions occur in the system.

References

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