IMPLEMENTATION OF PARALLEL PROGRAM FOR COMPOSITIONAL FLOW SIMULATION DURING OIL AND GAS FIELDS DEVELOPMENT USING DVM-SYSTEM

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Compositional multiphase simulation is used for more detailed flow modeling for reservoirs with light hydrocarbons (gas, condensate), for more accurate description of mass exchange between phases in enhanced oil recovery methods such as carbon dioxide or nitrogen injection, enriched gas injection or high-pressure gas injection, etc.

Equations governing the reservoir isothermal flow are the mass balance differential equations for the components representing reservoir fluids and displacing agents injected through wells, generalized Darcy's law, the equations of phase equilibria and some limitations on principle variables:

$$\frac{\partial}{\partial t}\left[\phi\left(\xi_o S_o x_i + \xi_g S_g y_i\right)\right] + div\left(\xi_o x_i \vec{W}_o + \xi_g y_i \vec{W}_g\right) - q_i = 0,\ i = 1,2,...,N_c, \qquad (1)$$

$$\frac{\partial}{\partial t}\left[\phi \xi_w S_w\right] + div\left(\xi_w \vec{W}_w\right) - q_w = 0, \qquad (2)$$

$$\vec{W}_\alpha = -k k_{r\alpha} \mu_\alpha^{-1}\left(gradP_\alpha + \rho_\alpha g\ gradD\right),\quad \alpha = o, g, w, \qquad (3)$$

$$f_i^o - f_i^g = 0,\quad i = 1,2,...,N_c, \qquad (4)$$

$$\sum_{i=1}^{N_c} x_i = 1,\ \sum_{i=1}^{N_c} y_i = 1, \qquad (5)$$

$$S_o + S_g + S_w = 1, \qquad (6)$$

$$P_o - P_w = P_{cwo},\ P_g - P_o = P_{cog},\ P_g - P_w = P_{cwo} + P_{cog}, \qquad (7)$$

where N_c - total number of components in oil and gas phases, k and ϕ - absolute permeability and porosity of the reservoir, t - time, P_α - pressure in phase α, S_α - saturation by phase α, x_i and y_i - molar concentrations for component i in oil and gas phases, ξ_α, μ_α, - the molar density, dynamic viscosity, mass density for phase α, P_{cwo}, P_{cog} - capillary pressures in oil-gas and in oil-water systems, $k_{r\alpha}$ - relative permeability to phase α, q_i, q_w - source/sink densities for components and water, $D(x, y, z)$ - the elevation above a horizontal plane, g - gravity acceleration, f_i^o и f_i^g - component fugacities in oil and gas phases.

These equations may be so transformed and combined that one equation may be treated as the pressure equation and the others are the mass balance equations for all components of overall reservoir system "water-oil-gas". In this case it is convenient to use IMPECS method for computations (implicit pressure, explicit concentrations of components and saturations). The pressure equation is nonlinear with regard to pressure, and the implicit method is used for its solution (with Newton linearization). Then, using explicit method the molar concentrations in mixture may be determined. This mixture may be flashed into two phases - oil and gas - using phase equilibria calculation methods at *T* and *P* given with x_i and y_i required. The system of differential equations and linear constraints representing the isothermal compositional simulator for simultaneous flow of oil, gas and water, is solved at given initial and boundary conditions. The application of some equation of state to describe the multicomponent mixture behavior allows to get consistent values of phase compositions in equilibrium and phase densities. The most popular equations of state Peng-Robinson, Redlich-Kwong, Redlich-Kwong-Soave are used in this simulator.

Equilibrium compositions, satisfying equations (4), are determined using equilibrium ratios successively recalculated with component fugacities in each phase and then using so called minimum variables method with quadratic convergence rate in the solution vicinity.

The main stages of parallel program development for compositional flow simulation using DVM-system[1] will be discussed in the report.

References

1. Bakhtin V.A, Krukov V.A, Chetverushkin B.N, Shilnikov E.V. // Doklady Mathematics. 2011. Vol. 84, No 3. pp. 879-881.