Stress and permeability of geomaterials and rock: theory and lab experiment

Nazarov L.A., Nazarova L.A., Golikov N.A.

Chinakal Institute of Mining Siberian Branch of RAS, Novosibirsk, Russia

e-mail: mining1957@mail.ru

The method for determination of dependence of oil-bearing rock (with high content of organic substance) rheological properties on temperature was developed and tested in laboratory conditions. The method is based on inverse problem solution by thermobaric tests data. The cylindrical specimen was subjected to static axial loading and stepwise heating from 20 to 150 C; time variation of specimen height H(t) was measured. Deformation of the specimen was described by Kelvin model, within which the inverse coefficient problem was solved (H(t) is input data) to determine Young module En and effective viscosity Vn at each stage T=Tn of heating. The obtained data sets En and Vn were approximated by two-parameter exponential functions, empirical relationships E=E(T) и V=V(T) were revealed.

The lab-scale test bench was designed and manufactured to study the relationship of granular geomaterials permeability K versus stresses. Measurement cell of parallelepiped shape was filled with sized sand of known granulometric composition; vertical stress S was applied to different sections of the top edge of cell. The constant gas pressure P was produced on one of vertical edges, while gas flow rate Q(S,P) was recorded on the opposite vertical edge in steady filtration regime. The mathematical model of experiment was developed to describe mass transfer process. Hypothesizing that K depends on effective stress according to the exponential law with coefficient G in index of power, the analytical solution was found to the problem on stationary filtration in a cell under a non-uniform stress state. The procedure was substantiated for quantitative estimation of G based on minimization of the relative discrepancy functional between Q and the theoretical gas discharge. It was established that G can be found independent of gas viscosity and an initial permeability of sand packing.

The poroelastic model of borehole environment was developed to describe evolution of geomechanical and hydrodynamic fields. The comparative analysis of well production characteristics for the typical deformation and poroperm properties was carried out. It was demonstrated that ignoring of the new-established empirical relationships of permeability on effective stress and temperature can result in an appreciable upward bias of oil production prediction.