Rheological Properties and Stress-Dependent Permeability of Reservoir Rock: Theory and Experiment

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1. Thermobaric tests are performed on Bazhenov oil-bearing shale containing above 10% of kerogen in view to determine its rheological properties. The test specimen under a static axial load is heated stepwise at temperatures T_n=60, 90, 120 and 150°C with measurements of specimen height $H(t)$. Deformation of the specimen is described by Kelvin-Voigt model, within which the inverse coefficient problem is solved to determine Young module E_n and effective viscosity η_n of rocks in terms of $H(t)$. The test data are approximated by two-parameter exponential functions, $E=E(T)$ and $\eta=\eta(T)$ relationships are established.

2. The lab-scale test bench is designed and manufactured to study the relationship of granular geomaterials on stresses. A polyurethane measurement cell of parallelepiped shape is filled with sized sand; controllable vertical stress σ is applied to different sections of the top edge. The constant gas pressure p is created on one of vertical edges, while gas flow rate $Q(p,\sigma)$ is recorded on the opposite vertical edge. The experimental mathematical model is elaborated. Hypothesising that permeability depends on effective stress according to the exponential law with coefficient α in index, the analytical solution is found to the problem on stationary percolation in a cell under a non-uniform stress. The researchers propose the process for quantitative estimation of α based on minimisation of the relative discrepancy functional between Q and the computed gas flow rate. It is appeared that α can be determined without reference to gas viscosity and an initial permeability of geomaterial packing. According to the present test results α magnitude used to reduce insignificantly with stress growth.

3. The poroelastic model of borehole environment was developed to describe evolution of geo-hydro-mechanical 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.

4. The method for determination of mass-transfer and filtration characteristics of fractured porous reservoir rocks, considered as dual permeable media is developed and tested under laboratory conditions. The filtration tests consist in series of three measurements of the flowrate in the specimen: standard scheme (Q_0), fractures are tamped at one end (Q_1) and at the second end (Q_2). The mathematical model is developed; analytical solution is found to the problem on the stationary filtration in a dual permeable medium; the inversion relations are derived based on the new solutions in view to calculate fracture k_1 and matrix k_2 permeability's as well as mass-transfer coefficient by using the measured flowrate values Q_0, Q_1 and Q_2. The analysis of the solution revealed weak stability of the inverse problem solution by input data, as this implies more rigorous requirements regarding measurement precision. The laboratory tests of the oil-bearing rock specimens of Bazhenov formation with well pronounced fracturing justifies that ratio k_2/k_1 lies within the range 0.04-0.055.

The reported study was carried out with partial support of the Russian Foundation for Basic Research (Projects No. 18-05-00830, No. 19-05-00689) and Program of Federal Scientific Investigations (Identification Number AAAA-A17-117122090002-5).