Numerical Modeling of the Mechanical Behavior of Poro-Elastic-Plastic Artificial Materials in the Process of Hydraulic Fracturing

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This work presents the numerical simulation results of porous-elastic-plastic materials' mechanical behavior, reproducing the filtration-capacitance properties of reservoir rocks. The authors perform numerical modelings of laboratory experiments conducted earlier at the Sadovsky Institute of Geospheres Dynamics of the Russian Academy of Science on an installation that allows conducting studies on fracture propagation under triaxial loading conditions. This work aims to study the dynamics of fracture propagation under various loading conditions using numerical modelings. For this purpose, we take into account the porous and elastoplastic properties of the medium under study.

The authors prepared a mathematical model to study the propagation trajectory and fracture shape of hydraulic fracturing in poroelastic plastic artificial materials: set a system of defining equations and fracture criteria. Then we prepared numerical models using a mechanical software package. We built a three-dimensional numerical elastoplastic model of the rock based on the geometry of the sample. Modeling includes setting a set of mechanical parameters: Young's modulus, Poisson's ratio, internal friction angle, dilatancy angle, and deformation criterion of failure. In the study, we used a ready-made physical and mathematical mechanical model depending on the pressure of Mohr-Coulomb and pore pressure. Next, a series of numerical mechanical calculations were performed using the extended finite element method.

As a result of numerical modeling using a software package, the authors obtain that in the poroelastic model of the sample, a plasticity zone appears in the region of the central well before the fracture begins to form. Then, as the fracture spreads, the plasticity zone along the fracture propagation path is preserved. Modeling the stress-strain state along the fracture trajectory shows asymmetric distributions of stresses, pressures, and porosity relative to the central well. It was caused by different pressure values in the injection and production wells used in a laboratory experiment to create pore pressure. Also, it leads to the formation of different fracture lengths towards the production and injection wells, which we see during laboratory experiments.