Development of an Integrated Model of Fracture Propagation in Unconventional Reservoirs at Microscale

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Abstract

When dealing with production of gaseous and liquid hydrocarbons from unconventional reservoirs, production engineers often deal with extremely low permeability of a reservoir. Such complication leads to a relatively small fluid drainage area, often spanning to not more than tens of meters from a wellbore. For efficient hydrocarbon recovery from unconventional reservoirs, drainage area should be significantly increased. The most promising stimulation method to increase the drainage area is hydraulic fracturing.

Hydraulic fracturing operation is a complex technological process with many parameters of influence and just a few low-resolution characterization methods to validate the result. In most cases, only general clues on the efficiency of fracturing operation can be obtained, often in the form of “fluid flow is higher than prior to stimulation” or “no increase in fluid flow is observed”. Specific details of fracture geometry, topology and physical behavior remain inaccessible by conventional testing techniques.

In the presented work, an effort is made to study, reproduce, and forecast fracture propagation in rock at micro-scale and nano-scale. As a part of the presented activity, a complex research project has been conducted to collect a broad self-consistent set of petrophysical, geomechanical, hydrodynamical, and rock structural data for one of Russian promising unconventional gas formation. For all the acquired data, a special focus has been set on accurate estimation of uncertainties. An important part of the dataset consists of a few multiscale digital rock models spanning from the scale of centimeters down to nanometers – these models encompass the smallest details representing rock structure at different scales, which will be useful for geomechanical and hydrodynamical modeling. Details of the geomechanical part of data processing and interpretation are presented in this work.

Future activity include a combining multiscale digital rock models with geomechanical data acquired in the scope of a few laboratory experiments, in order to build a representative geomechanical model of the studied rock type and to numerically simulate fracture propagation effects; to initialize this model with local mechanical properties acquired with nanoindentation method, including uncertainties; to develop an efficient numerical conversion method that allows translating multi-billion-cells voxelbased 3D rock model into a corresponding FEM representation; to apply domain decomposition and computational load balancing techniques to the FEM model as a part of HPC effort; to compute hundreds of probabilistic realizations of the FEM model due to uncertainties, using HPC and experimental design methodology – this approach falls into Big Data domain, since each model realization consists of multi-billion-cell geometry and gigabytes of supplementary data; to select the most probable realizations of fracture propagation in rock; finally, to calibrate the geomechanical model of rock to the global geomechanical properties which were acquired and processed as a part of the conducted study. The listed research steps can be unified under the scope of an experimentalcomputational workflow that integrates rock properties from a variety of experimental tests into a complex computational model and allows the use of such a model for fracture growth forecasting in the interest of industrial developers of unconventional gas and oil reservoirs.