Development of enhanced theory, numerical methods and computer programs for simulation of hydraulic fractures and accompanying seismicity in real time

The project aims to improve hydraulic fracturing, the operation widely used for stimulation oil, gas and heat recovery in the petroleum industry and thermal heat production. A hydraulic fracture (HF) treatment consists in pumping a fluid (commonly water) under the pressure high enough to create a crack (hydrofracture) in a productive layer. If a treatment is a success, it drastically increases the surface, to which oil (gas, heat) flows to the wellbore, what results in notable growth of recovery. Thousands of treatments are pumped each year. The importance of HF has dramatically grown last years because huge resources of gas are found in low permeable shales: in view of low permeability, it cannot be extracted without hydrofracturing.

HF, being a quite expensive operation, the success of a treatment is of prime economic significance. Meanwhile, in practice, far from all treatments are a success, because of scares information on the structure and properties of rock at the borehole depth. This strongly restricts understanding and control of the fracture initiation and propagation. Actually, there are merely two sources for making decisions; those are mathematical modeling and microseismic observations.

The mathematical modeling is the main way to increase understanding and to enhance efficiency of hydraulic fracturing. However in view of extreme mathematical and computational difficulties, caused by (i) moving fracture front, (ii) strong non-linearity of the problem, and (iii) singular behavior of physical quantities near the front, the existing numerical techniques are presently of excessive computational cost. They do not allow tracing the HF propagation and making decisions in real time. The need to dramatically speed up simulators of the fracture propagation is clearly recognized.

The project meets this challenge: its *objective is to create an enhanced theory, numerical methods and computer programs for simulation of hydraulic fractures and accompanying seismicity in real time*. The objective is feasible due to the recent progress in understanding the theoretical fundamentals which resulted in the modified formulation of the HF problem. The revised formulation suggests using the particle velocity, instead of conventional using the flux; the speed equation, instead of conventional using the global mass balance; and deriving and using universal asymptotics applicable to an arbitrary regime of the fracture propagation. These innovations open wide options for tracing HF by highly efficient methods of the theory of propagating interfaces, unavailable for the conventional formulation. They make possible tracing of a HF in real time. Meanwhile, using the new options for efficient tracing the front propagation aggravates the need to overcome the remaining mathematical difficulties. This challenge is to be met by special mathematical research and new computational techniques, based on numerical and asymptotic analysis and on the theory of hypersingular integral equations developed by the head of the project.

Simulation of the fracture propagation is to be complimented by numerical simulation of accompanying seismicity. Such an opportunity is presently suggested by the general theory of numerical modeling of seismic events. The comparison of (i) the simulated pumping history with that in a treatment and (ii) the synthetic seismicity with that observed in real time will serve to improve understanding of an ongoing process, to validate and to calibrate the uncertain input data.

The execution of the project will bring the theory and numerical methods of HF simulation on the level notably above the present state of art. This will provide a unique tool for modeling truly 3D problems in real time in field conditions. Complementing modeling of HF propagation with simulation of accompanying seismicity will mean a significant step in employing the field data on the measured pressure history and on observed microseismicity for decreasing the uncertainty and for enhancing the efficiency of HF treatments. Since thousands of treatments are pumped each year and much more are expected when employing resources in low permeable shales, the increase of the efficiency of this expensive operation will provide high economic gain.