**Description for the general public**

The aim of the 3-year experimental-theoretical research project is: a) the explanation of the mechanism of the initiation and propagation of fractures in rocks during hydro-fracking (fluid under high pressure) and b) its description with the use of the advanced mathematical model based on the extended discrete element method (DEM) that combines the mechanics of discontinuous bodies with the fluid mechanics and heat transport under 3D conditions. Since hydro-fracking strongly depends on a heterogeneous structure of rocks, the discrete element method is a suitable numerical tool for investigating this process at the mesoscopic level. The computational fluid dynamics (CFD) will be used within fluid mechanics (viscous fluid motion will be described by the Navier-Stokes equations). The calculations will be carried out for a two-phase (liquid- and gas-phase) laminar and turbulent flow of incompressible fluid, by taking the mass, momentum and heat transport into account in existing and newly developing fractures in rocks. The mechanical, fluid and heat flow properties will be measured on rock specimens and artificial rock materials composed of spheres. Our research works are innovative at the world scale because of their broad range of mutually complementary experiments and numerical simulations that employ the most recent measuring tools (the 3D x-ray micro-tomography system) and numerical tools (the coupled DEM/CFD approach that combines the mechanics of discontinuous bodies with the fluid mechanics and heat transport at the meso-structure level of rocks).

Research works consist of two complementary parts: experimental and theoretical ones. In the experimental part, two different comprehensive laboratory tests will be performed: 1) quasi-static strength investigations of two different rocks (e.g. shale and granite) during splitting tension and uniaxial compression and 2) quasi-static investigations of fluid flow characteristics in artificial materials composed of glass and rubber spheres subjected to the pressure of the fracturing fluid under isothermal and non-isothermal conditions by measuring fluid pressures, velocities and temperatures. Due to the use of the very advanced 3D micro-computed tomography system (owned by our department), the changes of meso-structure and fracture geometry in rock specimens will be observed due to the fluid pressure. In addition the scanning electron microscope will be also used to analyze changes of meso-structure on the rock surface. In the computational part, the coupled DEM/CFD model will be elaborated for rocks, that combines the mechanics of discontinuous bodies with the fluid mechanics and heat transport at the mesoscopic level under three-dimensional (3D) conditions. The calculations will be divided into 3 phases: 1) pure mechanical simulations, 2) coupled mechanical-hydraulic simulations and 3) coupled mechanical-hydraulic-thermal simulations. In mechanical calculations the effects of rock anisotropy, location and shape of naturally existing fractures, macro- and micro-pores, size and distribution of discrete elements on the rock behaviour will be investigated in detail. The mechanical-hydraulic calculations will be performed for the constant temperature (isothermal conditions). The effects of the flow type (laminar and turbulent flow) and fluid dynamic viscosity on fluid pressures and velocities will be investigated for different systems of natural fractures and permeability and porosity of rocks. The coupled mechanical-hydraulic-thermal analyses will be carried out for non-isothermal and turbulent fluid flow in rocks. The calculations will be performed with rock specimens initially containing gas and subjected to the fracturing fluid pressure. The filling process of pores by fracturing fluid will be investigated with respect to the velocity and range. Focus will be on the effect of pronounced and sudden grain displacement changes on fractures, fluid pressures and temperatures. Our innovative coupled DEM/CFD model will be validated based on our laboratory tests and other similar tests in the literature.

As a result of our research, a new knowledge-base on the mechanism of initiation and propagation of fractures in rocks during hydro-fracking will be created, by taking complex coupled mechanical-hydraulic-thermal effects at the meso-scale of rocks into account. The mesoscopic data will be next useful for formulating a macroscopic phenomenological constitutive model of hydro-fracking at the global scale. Our basic research works will next allow for creating tools for applied research works that allow to estimate in future the extraction productivity of gas, oil from rocks and heat from geothermal wells.