Geophysical Research Abstracts
Vol. 19, EGU2017-1597, 2017
EGU General Assembly 2017

Fluid driven fracture mechanics in highly anisotropic shale: a laboratory study with application to hydraulic fracturing

Stephan Gehne (1), Philip Benson (1), Nick Koor (1), and Mark Enfield (2)

(1) University of Portsmouth, Portsmouth, United Kingdom (stephan.gehne@port.ac.uk), (2) P.D.F. Limited, Ewelme, Wallingford, United Kingdom

The finding of considerable volumes of hydrocarbon resources within tight sedimentary rock formations in the UK led to focused attention on the fundamental fracture properties of low permeability rock types and hydraulic fracturing. Despite much research in these fields, there remains a scarcity of available experimental data concerning the fracture mechanics of fluid driven fracturing and the fracture properties of anisotropic, low permeability rock types.

In this study, hydraulic fracturing is simulated in a controlled laboratory environment to track fracture nucleation (location) and propagation (velocity) in space and time and assess how environmental factors and rock properties influence the fracture process and the developing fracture network.

Here we report data on employing fluid overpressure to generate a permeable network of micro tensile fractures in a highly anisotropic shale (∼50% P-wave velocity anisotropy). Experiments are carried out in a triaxial deformation apparatus using cylindrical samples. The bedding planes are orientated either parallel or normal to the major principal stress direction ($\sigma 1$). A newly developed technique, using a steel guide arrangement to direct pressurised fluid into a sealed section of an axially drilled conduit, allows the pore fluid to contact the rock directly and to initiate tensile fractures from the pre-defined zone inside the sample. Acoustic Emission location is used to record and map the nucleation and development of the micro-fracture network. Indirect tensile strength measurements at atmospheric pressure show a high tensile strength anisotropy (∼60%) of the shale. Depending on the relative bedding orientation within the stress field, we find that fluid induced fractures in the sample propagate in two of the three principal fracture orientations: Divider and Short-Transverse. The fracture progresses parallel to the bedding plane (Short-Transverse orientation) if the bedding plane is aligned (parallel) with the direction of $\sigma 1$. Conversely, the crack plane develops perpendicular to the bedding plane, if the bedding plane is orientated normal to $\sigma 1$. Fracture initiation pressures are higher in the Divider orientation (∼24MPa) than in the Short-Transverse orientation (∼14MPa) showing a tensile strength anisotropy (∼42%) comparable to ambient tensile strength results. We then use X-Ray Computed Tomography (CT) 3D-images to evaluate the evolved fracture network in terms of fracture pattern, aperture and post-test water permeability. For both fracture orientations, very fine, axial fractures evolve over the entire length of the sample. For the fracturing in the Divider orientation, it has been observed, that in some cases, secondary fractures are branching of the main fracture.

Test data from fluid driven fracturing experiments suggest that fracture pattern, fracture propagation trajectories and fracturing fluid pressure (initiation and propagation pressure) are predominantly controlled by the interaction between the anisotropic mechanical properties of the shale and the anisotropic stress environment. The orientation of inherent rock anisotropy relative to the principal stress directions seems to be the main control on fracture orientation and required fracturing pressure.