

STRESS MEASUREMENT BY HYDROFRACTURE

Sigra owns and operates equipment to measure stresses by a process of hydrofracture. This essentially involves straddling a section of uncased borehole with packers. Fluid (generally water, or water containing a viscosifier) is pumped between these packers and the pressure is raised until the borehole wall fractures and the fluid inflow rate increases indicating that a fracture has formed. Pumping is then stopped and the fluid in the fracture leaks off until the fracture closes. This closure is indicative of the minor principal stress. The re-opening pressure is a function of the minimum and maximum principal stresses perpendicular to the borehole.

The process of re-opening the fracture and then permitting it to close is generally repeated over several cycles to confirm the re-opening and closure pressures.

From this process Sigra can, in the case of an initially un-fractured borehole wall, determine the major stresses perpendicular to the borehole provided that the borehole lies in the axis of a principal stress. This stress determination can be accomplished for cases where there are small or large differences in the major stresses that may induce compressive or tensile loadings in the borehole wall. The theory on which the major principal stress is determined is based on elastic principals and cannot be applied to highly inelastic rocks.

Sigra may use the conventional approach of a constant injection rate. In this case several fracture re-openings must be undertaken at varying flow rates. This is because the re-opening pressure is dependent on the rate of injection and it is necessary to determine the theoretical re-opening pressure at zero flow rate. In some cases Sigra prefers to use a process of steadily raising the injection pressure until the flow rate increases rapidly and indicates fracture opening.

Sigra determines the orientation of the fractures created by hydrofracturing using either an orientated impression packer or through acoustic scanning techniques and from this determines the directions of the stresses.

In real situations the borehole may not be orientated in the direction of a principal stress and there may be



Fracture Trace on Impression Packer

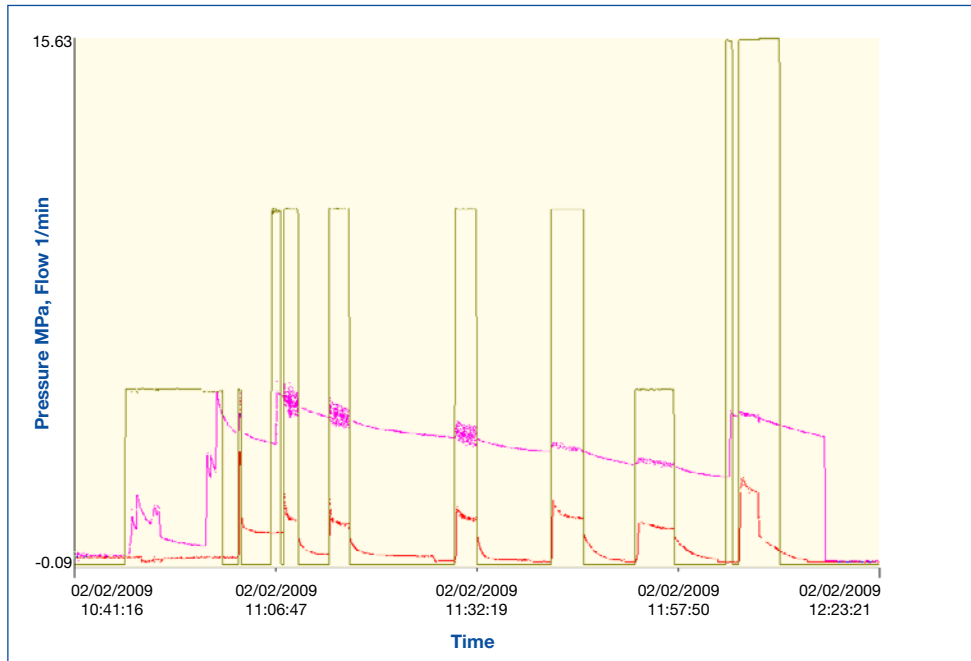
fractures in the rock and borehole wall. In the former case the fracture can be expected to rotate from the borehole wall into the plane of minimum principal stress away from the borehole wall thus complicating the analysis. Where pre existing fractures exist about the only stress that can be determined is the rock stress normal to these.

In the case of coal seams with significant permeability, high flows may be required to initiate a fracture and the fracture pattern is likely to be controlled by the cleating. This limits practical measurements to a minimum stress that may be determined from cleat closure pressure. If hydrofracturing is being used through perforated casing the level of complications increase further as the fracture cannot initiate in a preferred plane. This eliminates any possibility of determining the major principal stress using this technique.

Packer pressure must always exceed the pressure of the fluid being used in the hydrofracture process

otherwise leakage will occur around the packer. Therefore the probability of the packer initiating the fracture always exists. Such a fracture will have the same orientation as a fluid induced fracture. Keeping packer pressures to the lowest level compatible with sealing minimises fracture initiation problems.

Hydrofracture can still be a useful method to obtain an understanding of in-situ stresses when undertaken in the right situations and when analysed with suitable care. It is frequently the only option, particularly where a borehole has already been drilled thus precluding the option of overcoring.



Hydrofracture plot of total test sequence