Exploring in situ fracture hydromechanics from high resolution surface tilt and borehole strain observations

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Short abstract

Estimating the hydro-mechanical properties of fractured rock reservoirs is critical for many engineering practices. Laboratory and numerical experiments have brought considerable insights, but in situ hydromechanical experiments are relatively uncommon. We propose a new experimental design based on the combination surface tilt and borehole strain observations in classical hydraulic tests to access both local fracture behavior and its connectivity to the fractured network at 10 scales.

Regular Abstract

The quest for understanding flow through fractured media has mobilized tremendous research efforts because it drives a series of key processes like contaminant and heat transport or even failure that triggers microseisms or earthquakes [1]. Laboratory and numerical experiments have brought considerable insights, but in situ hydromechanical experiments are relatively uncommon.

Hydromechanical coupling (coupling between pressure-driven flow and fracture deformation, refered as HM) is well understood at laboratory scale, but is notoriously difficult to constrain *in situ* because of the high sensitivity of flow structures to small changes in fracture aperture, and network connectivity. The representation of a fracture network and its hydro-mechanical behavior remain as a daunting challenge considering the scarcity of appropriate data with respect to the volume of rock [2].

We present the development, testing, and analysis of a new high-resolution system for in-situ HM experiments, implementing surface tiltmeters (10^{-9} radian resolution, integrative) and borehole strain observations from fiber optics (1 cm spatial resolution, distributed) to monitor subsurface fracture deformation at depth in response to small amplitude sinusoidal pressure variations at its borehole inlets. This experimental setup have many advantages:

1. periodic pressure variations avoid the massive extraction or injection of water which might be impossible in specific contexts, due to logistical or security issues
2. controlling the oscillation frequencies enables the recovery of even the weakest signals
3. applying various oscillation frequencies allows for sampling different volumes of the subsurface around the tested well, providing a convenient way to assess scale dependencies of key properties
4. the small imposed pressure perturbation forms a limited mechanical disturbance on the tested fractures, and therefore, it is safe to assume that the hydrodynamic properties (T and S) are not significantly varying due to the hydraulic test itself;
5. distributed strain observations at the fracture's inlet captures active fractures and their behavior
6. surface deformation monitoring complements strain deformation and offers a wideror more integratedview on the mechanical response of an entire fracture network.

The methodology was applied on the Ploemeur hydrogeological observatory http://hplus.ore.fr/ploemeur/. We highlight the higher than expected density of active fractures and their lower than expected fracture stiffness [3].

References

[1] Guglielmi, Y., Cappa, F., Avouac, J. P., Henry, P., and Elsworth, D. (2015). Seismicity triggered by fluid injectioninduced aseismic slip. Science, 348(6240), 1224-1226.

[2] Rutqvist, J. and O. Stephansson (2003), The role of hydromechanical coupling in fractured rock engineering, Hydrogeol. J., 11, 7-40.

[3] Schuite, J., Longuevergne, L., Bour, O., Guihneuf, N., Becker, M.W., Cole, M., Burbey, T.J., Lavenant, N., Boudin, F. (2017) : Combining periodic slug tests and surface tilt measurements to explore in situ fracture hydromechanics, J. Geophys. Res., doi: 10.1002/2017JB014045

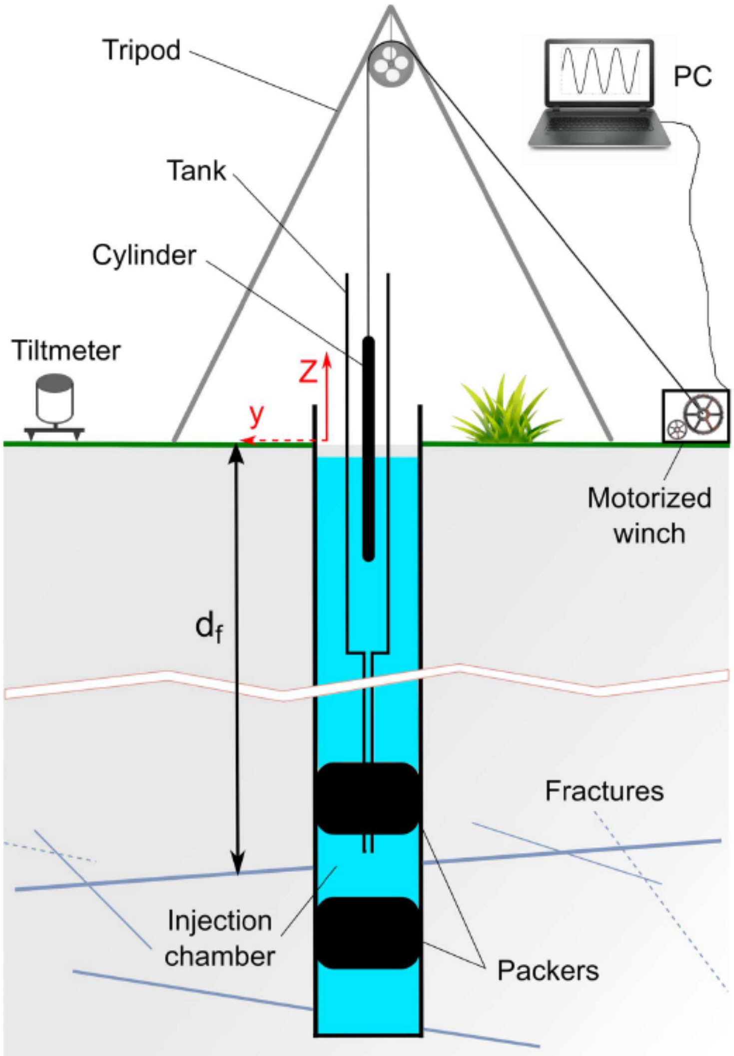

Figure 1: Experimental setup for sinusoidal testing. The tiltmeter is set at the surface, while FO strain measurements (not represented here) are set in a neighboring well.