Geophysical Research Abstracts
Vol. 18, EGU2016-793-3, 2016
EGU General Assembly 2016

Understanding Aero-Fractures using optics and acoustics

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In this work, analogue models are developed in a linear geometry, with confinement and at low porosity to study the instabilities that develop during fast motion of fluid in dense porous materials: fracturing, fingering, and channeling. We study these complex fluid/solid mechanical systems using two imaging techniques: optical imaging using a high speed camera (1000 fps) and high frequency resolution accelerometers. Additionally, we develop physical models rendering for the fluid mechanics in the channels and the propagation of microseismic waves around the fracture. We then compare a numerical resolution of this physical system with the observed experimental system.

The experimental setup consists of a rectangular Hele-Shaw cell with three closed boundaries and one semi-permeable boundary which enables the flow of the fluid but not the solid particles. During the experiments, the fluid is injected into the system, with a constant injection pressure, from the point opposite to the semi-permeable boundary. At large enough injection pressures, the fluid also displaces grains and creates large channels and thin fractures towards the semi-permeable boundary.

In the analysis phase, we compute the power spectrum of the acoustic signal in time windows of 5 ms, recorded by shock accelerometers Brüel & Kjaer 4374 (Frq. Range 1 Hz – 26 kHz) with 1 MHz sampling rate. The evolution of the power spectrum is compared with the optical recordings. The power spectrum initially follows a power law trend and when the channel network is developed, stick-slip events generating peaks with characteristic frequencies at 10, 30, 60 and 180 kHz are seen. These peaks are strongly influenced by the size and branching of the channels, compaction of the medium, vibration of air in the pores and the fundamental frequency of the plate. Furthermore, the number of these stick-slip events, similar to the data obtained in hydraulic fracturing operations, follows a Modified Omori Law decay with an exponent p value around 0.5. An analytical model of overpressure diffusion predicting p = 0.5 and two other free parameters of the Omori Law (prefactor and origin time) is developed. The spatial density of the seismic events, and the time of end of formation of the channels can also be predicted using this developed model. Using direct simulations of acoustic emissions due to the air vibration in opening fractal cavities, the evolution in the power spectrum is investigated.

1. Turkaya S, Toussaint R, Eriksen FK, Zecevic M, Daniel G, Flekkøy EG, Måløy KJ. "Bridging aero-fracture evolution with the characteristics of the acoustic emissions in a porous medium." Front. Phys.3:70. 2015 doi: 10.3389/fphy.2015.00070