Secrets Of Aero-fractures: A Dual (Optical/Microseismic) Study

Semih Turkaya[1], Renaud Toussaint[1], Fredrik Kvalheim Eriksen[1,2], Megan Zecevic[3], Guillaume Daniel[3], Eirik G. Flekkøy[2], Knut Jørgen Måløy[2]

1 Institut de Physique du Globe de Strasbourg, CNRS, Université de Strasbourg, 5 rue Descartes, 67084 Strasbourg Cedex, France
2 Department of Physics, University of Oslo, P. 0. Box 1048, 0316 Oslo, Norway
3 Magnitude, Route de Marseille 04220 Sainte Tulle, France

* turkaya@unistra.fr

ABSTRACT

In this work, analogue models are developed (similar to the previous work of Johnsen [1]) in a linear geometry, with confinement and at lower porosity to study the instabilities developing during fast motion of fluid in dense porous materials: fracturing, fingering, channeling (Figure 1). 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 and piezoelectrical sensors. Additionally, we develop physical models rendering for the fluid mechanics (similar to the work of Niebling [2,3]) in the channels and the propagation of microseismic waves [4] around the fracture (Figure 2). We then confront a numerical resolution of this physical system with the observed experimental system.

The experimental setup [5] consists in 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 the large enough injection pressures, the fluid also displaces grains and creates channels, fractures towards the semi-permeable boundary.

In the analysis phase, power spectrum of different timewindows (5 ms) obtained from the recorded signal are calculated. Then, 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 a characteristic frequency can be 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. Using direct simulations of acoustic emissions due to the air vibration in developing fractal cavities the evolution in the power spectrum is investigated.

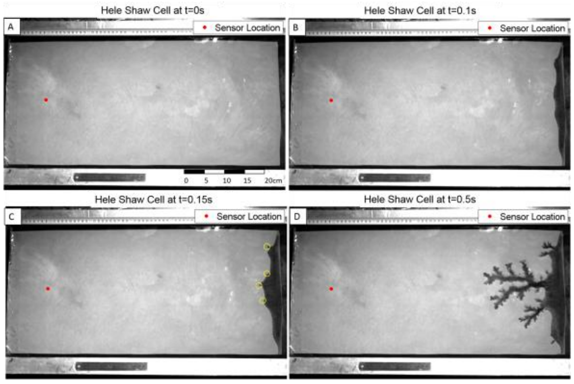

Fig. 1 Aerofractures in a Hele-Shaw cell during air injection.

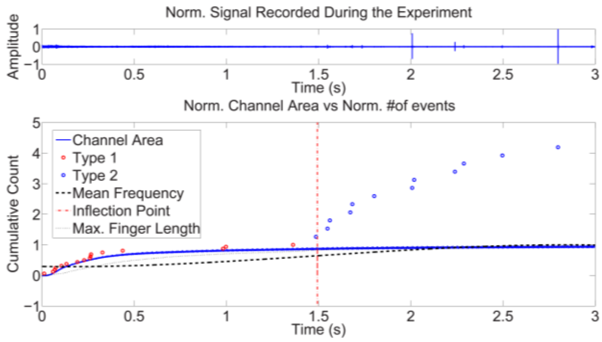

Fig. 2 Top: Signal during air injection inside the cell. Bottom: Number of acoustic events compared with carved area, maximum finger length and mean frequency.

References

1. Johnsen Ø, Toussaint R, Måløy KJ, Flekkøy EG. "Pattern formation during air injection into granular materials confined in a circular hele-shaw cell," Phys Rev E, vol. 74, no. 1, 2006.
2. Niebling MJ, Toussaint R, Flekkøy EG, Maløy KJ. "Dynamic aerofracture of dense granular packings." Phys Rev E, vol. 86, no. 1, 2012.
3. Niebling MJ, Toussaint R, Flekkøy EG, Maløy KJ. "Numerical studies of aerofractures in porous media." Revista Cubana de Fisica vol. 29 (2012) 1E66–1E70.
4. Farin M, Mangeney A, Toussaint R, De Rosny J, Shapiro N. "Etude expérimentale de l'emission acoustique par de petits impacteurs sur un solide élastique" CFA Proceedings, 2014
5. 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