AEROFRACTURES IN POROUS MEDIA: EXPLAINING MECHANICS WITH ACOUSTIC EMISSIONS

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Fluid induced brittle deformation of porous medium is an event commonly present in everyday life. From an espresso machine to volcanoes, from food industry to construction, it is possible to see traces of this phenomenon. In this work, analogue models are developed (similar to the previous work of Johnsen [1]) in a linear geometry, with confinement and at low porosity to study the instabilities that occur during fast motion of fluid in dense porous materials: fracturing, fingering, channeling (Figure 1a). We study these complex fluid/solid mechanical systems using two imaging techniques: optical imaging using a high speed camera (1000 fps), 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 compare a numerical resolution of this physical system with the observed experimental system.

The experimental setup [5] 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 the large enough injection pressures, the fluid also displaces grains and creates channels, 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. Different sources of the signal (air vibration in the carved area, changes in the effective stress due to fluid-solid interactions) are separately analyzed and are investigated further using a far field approximation of Lamb waves presented by Goyder & White [6]. In the analysis phase, power spectrum of different timewindows (5 ms) obtained from the recorded signal are computed. We found that, in the synthetic dataset, the peaks in the low frequency range ($f < 20$ kHz) diminishes while the medium fractures as suggested in experimental work.

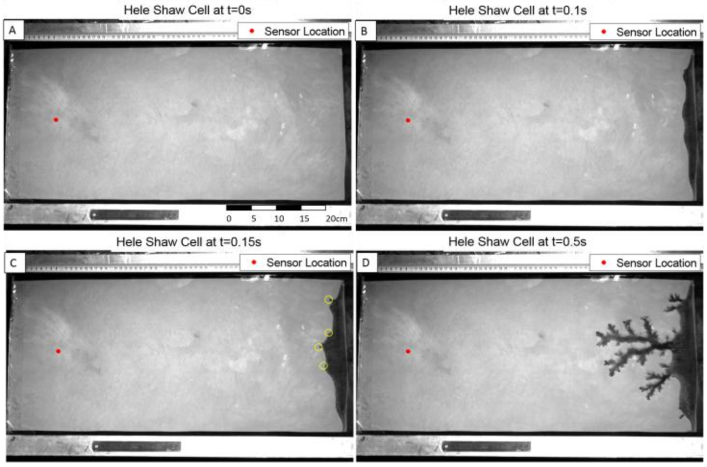

Figure 1. Aerofractures in a Hele-Shaw cell during air injection.

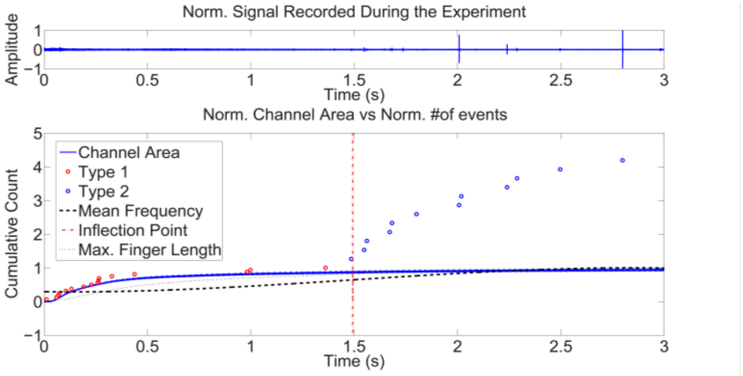

Figure 2. Top: Signal during air injection inside the cell. Bottom: Number of acoustic events compared with carved area, maximum finger length and mean frequency.

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