Revisiting sleeve fracturing for stress characterization

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Background

The magnitude of the maximum horizontal stress (SH_max) is a key input to many rock mechanics analyses (e.g., wellbore or fault stability analyses). However, there is no direct method available today to measure this stress component at great depth (i.e., >2 km), except the hydraulic test on pre-existing fractures (HTPF) method (Cornet and Valette 1984) and the hydraulic-sleeve fracturing combination (Desroches and Kurkjian 1994). However, HTPF method is ill-suited for sedimentary (heterogeneous) rock masses because, for a complete stress tensor determination, the stress field must be assumed to vary linearly across a minimum of five to eight tests. The Desroches and Kurkjian method is operationally difficult. The so-called sleeve fracturing method has been investigated since the mid-1980s as an alternative (Stephansson 1983; Ljunggren and Stephansson 1986; Charlez et al. 1987; Serata et al. 1992, Ito et al. 2001; Igarashi et al. 2008). Numerous issues were evident, including the pressure capacity required to create the second pair of fractures at great depth; the ability to interpret the initiation and reopening pressures on pressure-volume records or using various displacement/strain measurement devices coupled to the packer; interference between fractures; and the role of pore fluid pressure, particularly at fracture initiation. Our paper presents a fresh effort to revisit this technique and address some of the above-listed issues. This effort is ongoing, and our results must be taken as preliminary.

Results

We used pressure versus volume records to analyze 15 sleeve fracturing tests (each with one to four inflation/deflation cycles), performed with a wireline formation tester (Thiercelin et al. 1994) in three different US shale plays. In one case study, the sleeve tests were conducted after fractures were already created by hydraulic fracturing. Our main conclusions to date include the following:

- At least two fracture initiation and two reopening events could be observed in almost all the tests.
- The initiation and reopening pressures can be picked within +/– 30 psi.
- The initiation and reopening pressures are fairly consistent across all cycles within each test.
- In several cases, more than two events per cycle were observed, suggesting that more than two pairs of fractures are created, or that opposed fracture wings behave differently (or in an unsynchronized manner), or that some sort of stop-and-go propagation occurs
- In several cases, the cycles do not repeat, e.g., initiation may occur in late cycles only or reopening may disappear in late cycles, making event disambiguation difficult.

Figure 1 shows a clear reopening (showing as a decrease of the packer stiffness) followed by a clear breakdown (showing as a nearly constant pressure as volume keeps being injected).

In parallel, a numerical model was developed, based on the displacement discontinuity method, for the initiation, propagation and reopening of two pairs of orthogonal fractures driven by wellbore pressure increase (Fig. 2). The difference between initiation and reopening is captured by the use of a mixed stress and energy criterion (Leguillon 2002). We could verify that the two pairs of fractures do not interfere as long as the radial extent of the first one is short enough, in agreement with Serata et al. (1992).

Way forward

As already pointed out by many, displacement or strain monitoring is needed to locate and interpret creation/propagation/reopening events, and the pressure at which they take place. In particular, it is not clear whether the fractures are necessarily orthogonal (and the model may need to be improved in this respect). Furthermore, knowledge of the pressure in the fracture may be necessary to interpret such tests in terms of stress. These aspects call for further laboratory work and packer instrumentation.

Pending those improvements, sleeve fracturing tests would be a welcome addition to regular stress tests to constrain SH_max and enable the acquisition of more stress measurements because they are operationally easier and much faster to perform.

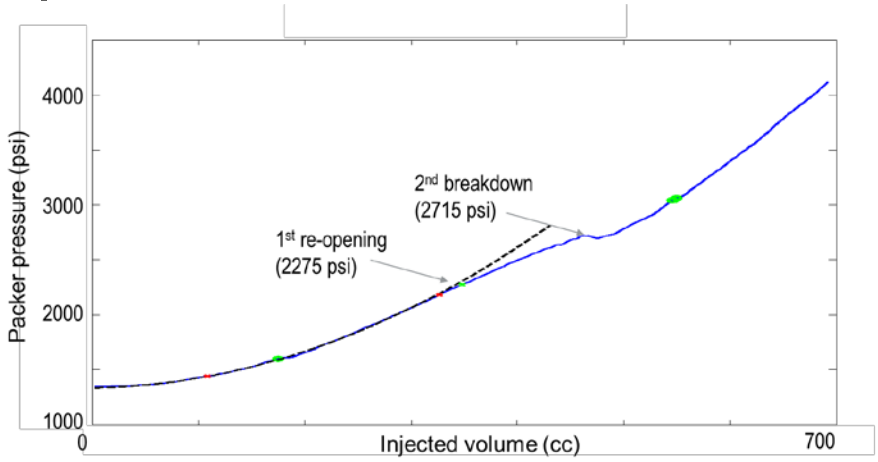

Fig. 1: Sleeve fracturing test following a hydraulic fracturing test. The first pair of cracks is being reopened, and a second pair of cracks is being created at a higher pressure

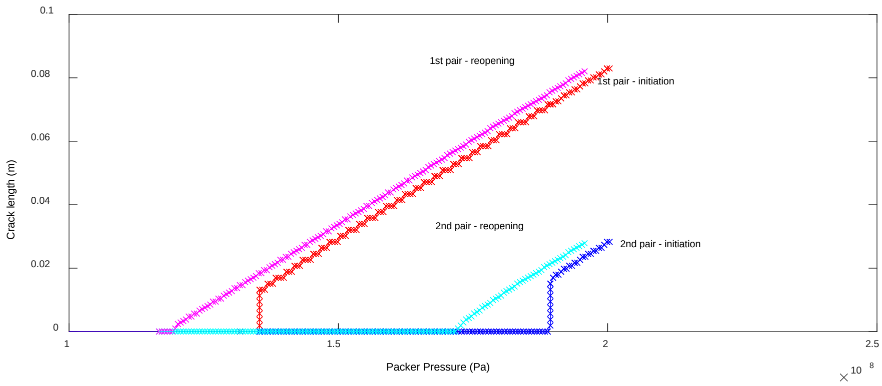

Fig. 2: Fracture extension from the wellbore for initiation and the reopening, for both pairs of fractures

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