Conductive Fracture Monitoring Using Distributed Strain Sensing: From Stimulation to Production

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ABSTRACT

Producers in unconventional reservoirs often experience rapid production decay due to the degradation and closure of stimulated hydraulic fractures. Understanding how fractures lose conductivity over the production period is essential for optimizing the development of unconventional reservoirs. Distributed Strain Sensing (DSS) measurements can be utilized to monitor conductive fractures during both stimulation (Jin and Roy, 2017) and production phases (Liang et al., 2022). In this study, we analyze data collected from a dedicated horizontal monitor well in Bakken to investigate changes in fracture conductivity from stimulation to production. The monitor well is drilled directly beneath an unconventional producer in the Bakken formation, with a varying vertical distance from the producer. It was instrumented with fiber-optic cables, allowing for DSS measurements during the hydraulic fracturing operation and during a well shut-in operation 17 months after the initial production. Additionally, 15 external pressure gauges were installed along the monitor well to observe pressure drawdown at different locations during production. Figure 1 presents a comparison of various types of measurements. Figure 1a illustrates the accumulated strain during the hydraulic fracturing operation for all stages. Only strain change during pumping periods is accumulated. Positive peaks indicate the locations of conductive fractures during stimulation, allowing for the easy identification of fractured zones along the monitor well. Figure 1b displays DSS measurements during a shut-in event after 17 months of production, with red indicating extensional strain changes that highlight fractures still conductive during the production period, while Figure 1d portrays borehole pressure measurements in the producer over the same period. Figure 1c shows pressure drawdowns after 17 months of production. An increase in strain intensity and fracture density from the DSS measurement during stimulation is observed as the vertical distance between the monitor well and the producer decreases from heel to toe (Figure 1a). However, no significant heel-to-toe bias is observed in either the DSS measurement during production (Figure 1b) or the pressure gauge measurements (Figure 1c). It is noteworthy that two pressure gauges in the monitor well's middle section indicate minimal drawdown, potentially due to their location relative to nearby conductive fractures or to gauge malfunctions. Nonetheless, the high spatial resolution of DSS measurement provides a more detailed assessment of the spatial distribution of conductive fractures. Upon comparing the conductive fractures during production with those during stimulation, we observed that only about 50% of the fractures remained conductive. Future research will focus on quantifying conductivity decay using reservoir simulation and characterizing the strain responses of long-lasting fractures during both stimulation and production to enhance our understanding of the longevity of hydraulic fractures in unconventional reservoirs.

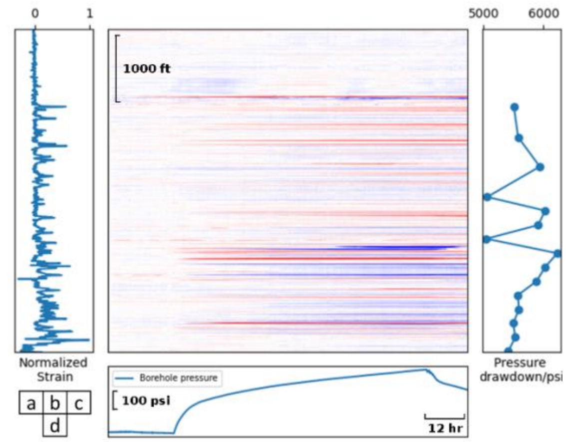

Figure 1: Comparison of different types of measurement on hydraulic fractures.
a) Cumulative strain change during hydraulic fracturing using DSS. The data are normalized.
b) DSS waterfall plot in the fracturing zone. Red parts are extending area and blue parts are compressing area.
c) Gauge pressure drawdown along measured depth.
d) The measured borehole pressure in the production well.

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