Hilbert Transform of Distributed Acoustic Sensing (DAS) fiber optic data: A new attribute to assess hydraulic fracturing in Marcellus Shale

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ABSTRACT

Distributed acoustic sensing (DAS) technology also known as distributed vibration sensing (DVS) utilizes optical fibers to measure the dynamic strain at all points along the fiber. Fiber optic distributed acoustic sensing (DAS) data was recorded for 28 stages in the MIP-3H well at the Marcellus Shale Energy and Environment Laboratory (MSEEL) outside of Morgantown West Virginia. We calculated two attributes to evaluate vibration frequencies around the fiber during the stimulation; they are calculated on each of the 493 traces for every 30 seconds during the hydraulic fracture stimulation (one SEGY file for every 30 seconds). The first attribute is the energy attribute: a summation of the squared amplitude of the DAS traces. Secondly, the DAS data are transformed into the Hilbert domain to calculate the instantaneous frequency attribute. Traditionally, the instantaneous frequency attribute of 3D seismic data is calculated for reservoir characterization in order to identify abnormal attenuation and thin bed tuning. It can also be used as a hydrocarbon indicator, since high frequency contents get attenuated more when encounter fluid. In this study, we show that instantaneous frequency attribute can be calculated for the DAS data to acquire details about vibration around the fiber. We use the average of the instantaneous frequency attribute calculated for every 30 seconds during the stimulation to detect abnormal vibration decay. Our result shows that instantaneous frequency reveals low frequencies in the stages below and above the stimulated stage while the energy attribute is only limited to the stimulated stages and does not show vibration in adjacent stages. The higher the energy attribute, the lower the instantaneous frequencies. Instantaneous frequency attribute is sensitive to the fluid existence; higher frequencies get attenuated faster than lower frequencies. Thus, higher energy attribute in the DAS data would be associated with high amount of injection fluid around the fiber and within the casing. Local low frequency zones in adjacent stages of the stimulation target might suggest temporary hydraulic connection via faults and fractures during the stimulation. We noticed low frequency zones in Stage 4 while stimulation of Stage 5. These local low frequency zones were also detected in the earlier stages of stimulated Stages 6, 10, 21, and 24. These findings could explain the observed abnormal temperature increase in the distributed temperature sensing.