Real-time Fracture Monitoring using Resonant Frequencies of Guided Waves: A Field Experiment

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Abstract

Objectives/Scope: Fracture monitoring is crucial for optimizing hydraulic fracturing and reducing the associated risk, but conventional microseismic methods struggle to extract useful information from weak signals. While wide azimuth acquisition apertures capture these signals, they are costly. A more cost-efficient approach estimates fracture conductivity in real-time from guided wave resonant frequencies recorded at the wellhead. A field experiment validated the effectiveness of this method, offering a simpler and cheaper alternative for fracture monitoring in hydraulic fracturing.

Methods, Procedures, Process: The proposed method estimates fracture conductivity in real-time by analyzing guided wave resonance frequencies. The procedure involves deploying broadband sensors at the wellhead before hydraulic fracturing, recording seismic waves during the process, extracting reflected guided waves from the full wavefields, performing time-frequency analysis on the reflected guided waves, extracting resonance frequencies of the guided waves, and mapping them to the fracture conductivity. The fully automatic data processing procedure can provide real-time fracture conductivity information during hydraulic fracturing. The method offers a simple and efficient way for fracture monitoring, increasing the safety and effectiveness of hydraulic fracturing operations.

Results, Observations, Conclusions: A field experiment was conducted to verify the effectiveness of the proposed method. A single three-component sensor was attached to the wellhead to record vibrations during hydraulic fracturing. The recorded vibration data was analyzed using a time-frequency analysis, which revealed the clear resonance frequencies with a spacing that was highly relevant to the fracturing treatment curves. The resonance frequency tracking algorithm was used to extract these frequencies with high precision, allowing for the estimation of fracture conductivity. This fully automatic procedure can be performed in real-time at each stage of hydraulic fracturing. Comparing conductivity histograms at different stages provides a relative and robust evaluation of fracturing quality throughout the treatment process. These results highlight the value of the resonance frequencies of guided waves for fracture monitoring during hydraulic fracturing.

Novel/Additive Information: This abstract presents a novel method to estimate fracture conductivity by analyzing the resonance frequencies of guided waves. Unlike the conventional passive seismic method, which requires many sensors to record weak body waves, only a few sensors are needed for this method to record strong guided waves, making it robust and cost-efficient. A field experiment verifies that this method can provide real-time information about fracture conductivity, which is crucial for optimizing hydraulic fracture treatment.