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Fracture and Fluid Prediction from Full-Wave Sonic Data by Higher-Order Normalized Differential Energy Methods

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ABSTRACT

Amplitudes of full-wave sonic (FWS) data are affected by both formation properties and borehole conditions, such as borehole rugosity, mode conversions and coupling effects. In contrast, calculating the energy of each wave component is found to be robust against distortions caused by noise and mode conversions. Recorded energy differentials can further reduce the influence of borehole rugosity and cancel out transmitter/receiver coupling effects. A typical method in using energy difference analysis, Normalized Differential Energy (NDE), is used to measure and normalize the energy changes between different offsets for a wave component. But conventional NDE largely suffers from three drawbacks. Firstly, the 1st-order differential is incapable of modeling practical FWS energy loss phenomena. Secondly, assuming velocity to be constant along the offset spread is inaccurate at a log scale. Also, resultant energy loss from the NDE methodology is usually less optimized because it fails to incorporate information from neighboring traces. To improve this situation, we propose a high-order NDE methodology from an inversion perspective, in which nonstationary shaping regularization is adopted to incorporate neighboring trace information and also allow velocity change among adjacent channels. By applying Chebyshev decomposition to this new concept, it can be shown that energy loss is not constant with respect to offset. In practice, we have applied this methodology to several FWS datasets and the results show improved fracture resolution compared with the conventional NDE method. Additionally, hydrocarbon and water are found to behave differently on the 2nd-order NDE result using low-frequency Stoneley waves, which may suggest a potential method for fluid identification.