Crossed-Dipole (HTI-F) Anisotropy Frequency Analysis

UNDERSTAND MECHANISM OF HTI ANISOTROPY

OVERVIEW

Sonic crossed-dipole anisotropy analysis—the analysis of shear- slowness characteristics around the borehole—is modeled in the industry as a formation with horizontal transverse isotropy (HTI). This symmetry is usually appropriate for naturally fractured or tectonically stressed formations penetrated by a vertical wellbore.

The waveform data from an Xaminer®-level crossed-dipole sonic tool is analyzed with the anisotropy waveform-processing model to obtain the fast and slow shear-wave traveltimes and their orientation in the formation. The anisotropy analysis processing engine is an analytical inversion technique that uses all crossed- dipole waveforms, from the in-line and crossed-line transmitter- receiver arrays.

To gain a better understanding of the mechanism that caused the anisotropy, an analysis in the frequency domain is performed simultaneously with the standard time-based analysis. In a regional stress environment, the angle of anisotropy will vary with respect to the time-based measurement as a function of frequency. This change is illustrated by a "flip" in color on the relative angle VDL palette from red to green. The dispersion curves as well exhibit a "crossover" effect, which is displayed on the signed percent anisotropy VDL as a color change from red to green. In a fractured environment or when there are dipped beds present, there will be no change in angle as a function of frequency nor will the dispersion curves crossover, and both VDLs will remain red throughout the frequency band.

ANISOTROPY ANALYSIS BENEFITS

The minimum and maximum principal stresses and stress-field orientation are calculated by combining oriented slowness data from this anisotropy analysis with overburden and pore-pressure data. This stress-field information is vital for geomechanical analysis, wellbore stability, and production enhancement treatment design (3D stimulation design and optimization of perforation phasing).

Sonic anisotropy and the orientation of the anisotropy can also be used to enhance 3D seismic interpretation and to determine the orientation of natural fractures systems with strike aligned near the borehole axis.

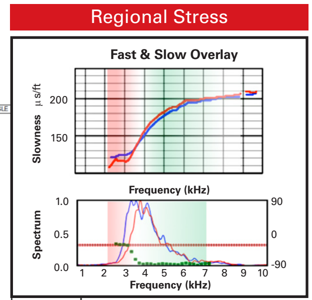
Sonic attributes, such as P-wave slowness and fast shear-wave traveltime, can be used for identification of compressive fluids in the pore space. Pore fluid identification allows planning for the best completion method and builds reservoir understanding to be applied to the next well.

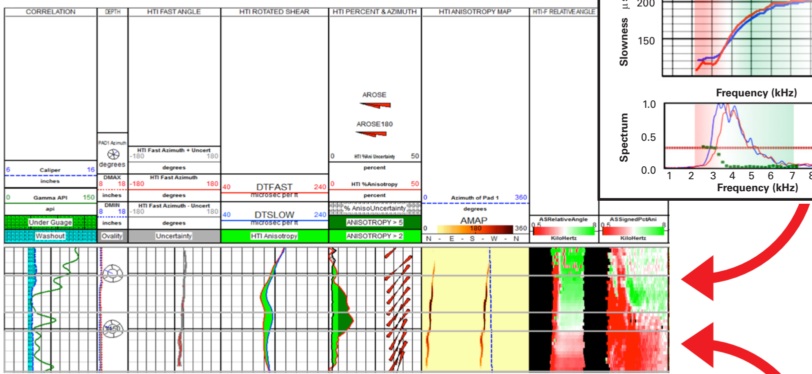
CROSSED-DIPOLE (HTI-F) ANISOTROPY FREQUENCY ANALYSIS FEATURES

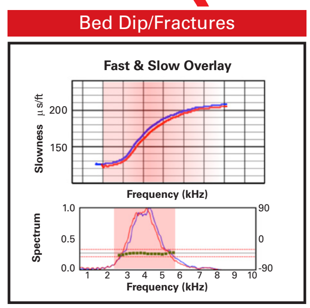
The broadband firing of the Xaminer®-level dipole sources allows for a full-frequency analysis and the generation of mechanism plots for visually identifying the possible causes of the anisotropy that can then be confirmed with other sensors, such as resistivity and acoustic imaging.

The Xaminer-level tools provide simultaneous monopole and crossed-dipole sonic information. The low-frequency portion of the flexural wave (excited by the modally pure broadband dipoles) travels at the true shear slowness of the formation. As a result, dispersion corrections for shear-wave slowness are not required for the anisotropy analysis.

The Xaminer Sonic Imager records eight azimuths of waveform array data (compared to the standard of four), which improves the signal-to-noise detection of the fast anisotropy azimuth.







This is an example of regional stress transitioning into fracture anisotropy. The fast and slow shear-wave traveltimes are presented in Track 4. The azimuth of the fast shear wave is presented in Track 3 along with its uncertainty. The percent anisotropy is presented in Track 5 and shaded when the anisotropy is greater than 5%. The anisotropy is also presented in an image on Track 6. North is on the right-hand and left-hand edges of the plot, and South is in the middle. The color intensity is proportional with the magnitude of the anisotropy. The rose plots in Track 5 show the change in azimuth of the anisotropy. Tracks 7 and 8 are the additional frequency analysis. Track 7 displays the change in angle as a function of frequency shaded between red (0° difference from Time-Based angle and Frequency-Based angle) to green (90° difference from Time-Based angle and Frequency-Based angle). Track 8 displays the difference between the fast and slow dispersion curves as a function of frequency shaded between red (fast – slow < 0), white (fast = slow) and green (fast – slow > 0).

ASSOCIATED ANSWER PRODUCTS

The following answer products are associated with Anisotropy Frequency Analysis:

» Xpert™-series processing – for example, Sand Production and Fracture Strength Analysis, Mechanical Properties, and Fracture Stimulation Zoning Analysis

Crossed-Dipole (HTI-F) Anisotropy Analysis

Inputs	Navigation data, all in-line and cross-line dipole wave-forms. Caliper.
Outputs	Relative angle, signed % anisotropy, and back rotation similarity as a function of frequency.
Requirements	Broadband dipole firing (Xaminer® Level)
Assumptions	One axis of wellbore to formation symmetry along the horizontal plane.
Complementary Products	Resistivity/Acoustic imaging to differentiate between dipped beds and fractures, and validate regional stress (borehole breakouts, hydraulic fractures). C44 and C55 stiffness components.

For more information, contact your local Halliburton representative or visit us on the web at www.halliburton.com

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