Seismic characterization of fractures

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Fractured geological formations are generally represented with a stress-strain relation based on a transversely isotropic medium with a horizontal symmetry axis (HTI medium). The detection of fractures and fluid saturation requires a proper model. We consider two cases.

First, an HTI layer embedded in an isotropic medium. The HTI medium is anelastic, whose viscoelastcity is described by the mesoscopic loss model (Carcione et al, 2011). The medium is partially saturated with two fluids (all combiantions of water, oil and gas) and is described by 5 complex and frequency dependent stiffnesses. Fracture strike is another important feature, which is related to the orientation of the symmetry axis with respect to the direction of the seismic profile. We compute the reflection coefficients of the layers as a function of the layer thickness, azimuthal angle and offset (AVO and AVA) to analize the possibility of evaluation of the fracture strike, anisotropy parameters, fluid saturation and fracture normal and tangential stiffnesses which give information about the fluid type and fracture density (e.g. Liu et al, 2000) and possibly porosity and permeability. The problem is three dimensional and it is a generalization of the single interface problem solved by Schoenberg and Protazio (1992). All the required methods and numerical techniques are available in Carcione et al (2011, 2012a,b,c, 2013). This theoretical analysis is essential to understand the physics of the problem. Then, full wave simulations based on the recently developed code (Gauzellino et al, 2014) generalized to the 3D case will be performed to compute surface seismic and VSP responses (Bakulin et al, 2000; Grechka and Tsvankin, 2003).

The second significant model that we have defined is an HTI layer overlying an isotropic layer half-space. The purpose here is to study the kinematc characteristics of the interface to perform a correct NMO correction of the reflection event versus offset and azimuth. Simulations will be performed with a full-wave solver to compute synthetic seismograms and verify the accuracy of existing NMO corrections equations (Grechka et al. 1999). The forward modeling is based on a pseudospectral Fourier method and spectral time intergration (Carcione et al , 1992) and on the new anisotropic and viscoelastic modeling code mentioned above and based on the finite-element method in the frequency domain (Gauzellino et al, 2014).

References

Bakulin, A., Grechka, V., and Tsvankin, I., 2000, Estimation of fracture parameters from reflection seismic data - Part I: HTI model due to a single fracture set, Geophysics, **65**, 1788-1802.

Carcione, J. M., Kosloff, D., Behle, A., and Seriani, G., 1992, A spectral scheme for wave propagation simulation in 3-D elastic-anisotropic media, Geophysics, **57**, 1593-1607.

Carcione, J. M., and Picotti, S., 2012a, Reflection and transmission coefficients of a fracture in transversely isotropic media, Stud. Geophys. Geod., **56**, 307-322.

Carcione, J. M., Picotti, S., Cavallini, F., and Santos, J. E., 2012b, Numerical test of Schoenberg-Muir averaging theory, Geophysics, **77**, 27-35.

Carcione, J. M., Santos, J. E., and Picotti, S., 2012c, Fracture-induced anisotropic attenuation Rock Mech. Rock Eng, **45**, 929-942.

Carcione, J. M., Gurevich, B., and Santos, J. E., and Picotti, S., 2013, Angular and frequency dependent wave velocity and attenuation in fractured porous media, Pure and Applied Geophysics, **170**, 1673-1683.

Carcione, J. M., Santos, J. E., and Picotti, S., 2011, Anisotropic poroelasticity and wave-induced fluid flow. Harmonic finite-element simulations, Geophys. J. Internat., **186**, 1245-1254.

Gauzellino, P., Carcione, J. M., Santos, J. E., and Picotti, S., 2014, A rheological equation for anisotropic-anelastic media and simulation of synthetic seismograms, Wave Motion, 51, 743-757.

Grechka, V. and Tsvankin, I. 2003, Feasibility of seismic characterization of multiple fracture sets, Geophysics, **68**, 1399-1407.

Grechka, V., Tsvankin, I., and Cohen, J. K., 1999, Generalized Dix equation and analytic treatment of normal-moveout velocity for anisotropic media, Geophysical Prospecting, **47**, 117-148.

Liu, E., Hudson, J. A. and Pointer, T., 2000, Equivalent medium representation of fractured rock, J. Geophys. Res., **105**, 2981-3000.

Schoenberg, M., and Protazio, J., 1992, Zoeppritz rationalized and generalized to anisotropy, Journal of Seismic Exploration, **1**, 125-144.