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SIMULATION OF SEISMIC WAVES IN ANISOTROPIC MEDIA

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The seismic wave propagation modeling is a worthy tool that can be applied to the characterization of natural fracture systems. In general, seismic wavelengths are tens to hundreds of meters and greater than the spacing and the opening of these fractures, so it is possible to consider the subsurface as an equivalent anisotropic medium. Analyze: (a) different models of effective anisotropy, (b) the relationship among physical properties of fractures, anisotropic parameters and seismic data, (c) type of seismic experiments in order to obtain informations of the systems and (d) characteristics such as fracture intensity (number of fractures per meter), orientation (azimuth) and properties of the material that infills the fractures using surface and well seismic data, it can be carried out by means of numerical simulations.

This work presents a wave propagation formulation in the space-frequency domain that is naturally posed with the inclusion of attenuation and dissipative effects via the use of complex frequency-dependent viscoelastic coefficients in the stress-strain relations. First-order absorbing boundary conditions are derived and used to minimize spurious reflections from the artificial boundaries. The solution is computed for a finite number of temporal frequencies (Helmholtz-type boundary value problem) and the space-time domain solution is obtained via an approximate inverse Fourier transform. A nonconforming finite element method is used to solve this problem in two and three dimensional media. Previous studies highlighted that the nonconforming method introduces less numerical anisotropy and is less dispersive than the conforming method yielding the same order of spatial approximation. For a given fixed accuracy requirement, using the former permits to nearly half the number of points per wavelength needed by the latter to achieve it. In addition, when parallel codes are implemented the nonconforming method requires lower transmission load.

Numerical experiments show the potential applicability in exploration and production of hydrocarbons. The seismic response is related to different types of fractures which are interpreted as effective anisotropy media with monoclinic symmetry, orthorhombic, and transversely isotropic symmetries.

The complexity of structures that can be found, with several material layers, fracture intensity and orientation, irregular shapes, etc, drives the need to use a powerful pre and post processor. In this work, the pre and post is developed using Abaqus/CAE. In order to do that, in a first approach, a FORTRAN code is developed. This code reads the Abaqus input file and transforms from parabolic conformed to non conformed finite elements. All properties related to material data, failure position and behavior, sensors, boundary conditions and loads are defined inside Abaqus and are transformed and transferred to the solver. When the solution is achieved, another code realize the inverse transformation and imports the results to Abaqus for the post process.

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