Geophysical Research Abstracts
Vol. 20, EGU2018-1603-2, 2018
EGU General Assembly 2018

Seismic wave modelling in 2D poroelastic media using the second order frequency-domain finite difference method

Xu Liu and Stewart Greenhalgh

College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum & Minerals, Saudi Arabia (liu.xu@kfupm.edu.sa)

Most numerical approaches to solving the poroelastic wave equations are carried out in the time domain which involves a convolution associated with a frequency-dependent dynamic permeability. The problem of “stiff equations” arises due to the existence of the Biot slow P-wave. Under a low-frequency approximation the normal time-dependent relaxation functions can be separated into just two linear terms, enabling a split method to be used (Carcione & Quiroga-Goode, 1995).

A solution in the frequency domain can circumvent the complicated time domain convolution, which is replaced by a simple spectral multiplication, and can easily handle the complex moduli and dynamic permeability over the full frequency range. Furthermore, in this domain, the discretized seismic wave equations reduce to solving a system of linear equations, with left hand side equal to the impedance matrix multiplied by the unknown wavefield vector and a source vector on the right-hand side. The wavefields encountered in porous media include the solid particle displacement, the fluid flux, the total stress and the fluid pressure. Using a first-order partial differential equation system (Liu, et al, 2014), the wavefield vector includes all four wavefield types, thus making the equation set extremely large. But in the second-order PDE system, obtained by substitution, only two types of wavefield need to be considered. . The 2nd order differencing scheme leads to a well-structured, banded diagonal matrix (Stekl & Pratt, 1998). However, unlike the first-order system, the second-order system can be formulated to solve the poroelastic wave equations for either a homogeneous or heterogeneous model by appropriate choice of spatial derivatives of the physical parameters (Stekl and Pratt, 1998). Previous treatments have ignored such derivatives even for inhomogeneous media.

Here we use a 2D mixed-grid 9-point stencil and a staggered-grid finite-difference method (Stekl & Pratt, 1998) to solve the secondary-order Biot equations in the frequency domain. The mixed grid means a combination of two staggered-grid stencils on the classical Cartesian frame and a 45 degree rotated grid. The heterogeneous formulation is applied in parallel with the homogenous formulation to compare results. To attenuate spurious waves reflected from the edges of the model, a nearly perfectly matched layer technique (NPML) is implemented. The algorithm is validated by testing the numerical solution of an example homogeneous poroelastic model against the analytical solution. By next comparing results of the two numerical formulations (homogeneous and heterogeneous) for an inhomogeneous model, we establish the errors in inappropriate use of the homogeneous formulation

References

Carcione, J.M. & Quiroga-Goode, G., 1995. Some aspects of the physics and numerical modelling of Biot compressional waves, Journal of Computational Acoustics, 3(4), 261-280.

Liu, C., Yang, Q.J., Guo, Z.Q., Liu, Y., Lan, H.T., Geng, M.X., and Wang, D., 2014, Simulation of wave propagation in two-phase porous media using a frequency-space domain method, Chinese J. Geophys. (in Chinese), 57(9), 2885-2899.

Stekl, I and Pratt, R.G., 1998, Accurate viscoelastic modelling by frequency-domain finite differences using rotated operators, Geophysics, 63(5), 1779-1794.