Introduction

It has been suggested that the dispersive nature of reverberatory modes in anisotropic waveguides may be sensitive to the anisotropic parameters (Lou and Crampin, 1993). Unlike wave propagation in isotropic waveguides simple analytical expressions do not exist for calculating the guided wave dispersion in anisotropic waveguides. In anisotropic waveguides the particle motion does not decouple into pure transverse (Love modes) or pure radial-vertical (Rayleigh modes) except for propagation in symmetry planes. Instead generalized modes exist with motion in three dimensions. The dispersion curves for these modes correspond to roots in the frequency (f)-slowness (p) domain of the expression:

\[ \det[I - R_u(f,p) R_d(f,p)] = 0. \]

\( R_u \) and \( R_d \) are, for anisotropic media, 3x3 reflectivity matrices with subscripts \( u \) and \( d \) indicating upgoing and downgoing waves respectively (Kerry 1981, Frazer and Fryer 1984) and \( I \) is the identity matrix. In this work we match the observed dispersion for wave propagation in an anisotropic waveguide with theoretical dispersion curves using a Genetic Algorithm (GA) in an inversion role. GA’s are optimization tools that are able to deal with large, highly non-linear and multi-modal model spaces. Just as simulated annealing attempts to mimic the energy minimization that naturally occurs during crystallization, GA’s attempt to simulate evolution by natural selection, reproduction and mutation. This may be achieved by working with a pool of models, analogous to a population, which are in a coded format, analogous to chromosomes, which are then manipulated by various genetic processes.

Inversion

The GA inversion scheme is applied to dispersive wave modes observed in an in-seam seismic experiment conducted by British Coal (Liu et al., 1992). The source and 3-component geophones were located in a 2.4m thick coal seam with a separation of 150m. The source used was a nylon rod inserted in a 2m deep hole, orientated either perpendicular or at 45° to the coal face. To generate seismic energy the exposed end of the rod was struck on the exposed end imparting an impulsive impact polarized in the direction of the rod. The Coal has low P- and S-velocities and is likely to be an anisotropic medium with orthorhombic symmetry due to the existence of two orthogonal cleat systems. Therefore a coal seam sandwiched between two halfspaces with higher velocities acts as a suitable anisotropic waveguide. Selected seismograms from the experiment are shown in figure 1 and clearly show dispersion. These seismograms are analysed using a multiple filter technique (Dziewonski et al., 1969) and the results plotted on a frequency-slowness contour plot (figure 2). The GA is applied to maximise the observed energy summed along discrete frequency and velocity points defined by the calculated theoretical group velocity dispersion curves.

Conclusions

The results suggest that two generalized modes are excited in the coal seam. Synthetic seismograms corresponding to the model used to generate the group velocity dispersion curves shown in Figure 2 have been calculated and show good agreement with the recorded seismograms. We will show group-velocity dispersion curves which suggest that guided waves are sensitive to anisotropy. This technique may prove useful in monitoring EOR experiments or coal bed methane extraction.

References


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**Figure 1** - Seismogram recorded on **a)** the radial and **b)** the transverse geophone components showing the dispersive nature of the waves. The source was effectively aligned in the transverse direction.

**Figure 2** - Dispersion contour map for the seismogram shown in **Figure 1b**. Light areas correspond to high amplitudes and dark areas to low amplitudes. The asterisks denote the calculated group velocity dispersion for the best fitting model.