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A Modelling Study Of Broadband Seismic Wave Propagation In A Deep Mine

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SUMMARY

Understanding the propagation of seismic waves in a presence of very strong elastic contrasts, such as topography, tunnels and ore-bodies is still a challenge. Safety in mining is a major concern and seismic monitoring is the main tool here. For engineering purposes, amplitudes (peak particle velocity/ acceleration) and travel times of seismic events (mostly blasts or microseismic events) are critical parameters that have to be determined at various locations in a mine. These parameters are useful in preparing risk maps or to better understand the process of spatial and temporal stress distributions in a mine. Simple constant velocity models used for mine monitoring, cannot explain the observed complexities in scattered seismic waves. In hard-rock environments modelling of elastic seismic wavefield require detailed 3D petrophysical, infrastructure and topographical data to simulate the propagation of seismic wave with a frequencies up to few kilohertz. In this study, the effects of strong elastic contrasts on the propagation of broadband seismic waves will be illustrated using 2D/3D finite difference method.

Introduction

Safety is a major concern in deep mines, and movements in rock mass need to be monitored on a regular basis. Mine development imposes stress changes in the surrounding rock that typically induce or trigger seismicity with a wide range of magnitudes. These microseismic events typically have high frequency content up to few kHz that leads to small wavelengths in the order of few meters in hard rock environments.

In an active underground mine site, controlled production blasts and microseismic monitoring are conventionally the main tool to better understand the process of rock fracturing and rock deformation. In addition to these methods, this study uses cross-well travel time tomography for monitoring with a repeatable controlled source, similar to exploration methods.

In a mine, the presence of very strong elastic contrasts, such as massive orebodies, tunnels, stopes and infrastructure have a significant impact on the propagation of seismic waves. For such heterogeneous medium travel time and amplitude of seismic waves derived from the conventional constant velocity models are inadequate. Since the complexity of seismic wave propagation can affect the distribution of energy significantly, the use of a more accurate model is required to predict the ground motion. For example, the conventional empirical method used to calculate peak particle velocities and accelerations (PPVs/PPAs), tends to underestimate the intensity of seismic waves in stopes or areas close to blast sites, which could be corrected if a more realistic model was implemented.

In this study, the complexity of scattered seismic waves due to effects of strong elastic contrasts will be illustrated using a 2D/3D finite difference modeling method [Bohlen, 2002].

Method

With the recent availability of detailed 3D rock property models of mines, in addition to the development of efficient numerical techniques and parallel computation facilities, a solution for the propagation of seismic waves at the mine size level is achievable. In order to model the effects of high elastic contrasts on the propagation of seismic waves within a 3D underground mine, a full elastic/viscoelastic finite difference time domain modeling package is used [Bohlen, 2002].

To visualize the possible effects, a vertical 2D section from a 3D detailed petrophysics model of an underground mine was used here and illustrated in figure 1. Model dimension is 640 m x 640 m x 480 m in x, y and z direction respectively. A Ricker wavelet signal with a varied central frequency of 50, 150, 500, 1000 Hz was used here. The model is discretized into structured grids with the grid cell sizes varied between 0.25 m to 2 m, chosen based on the selected source central frequency for each simulation.

Figure 1 On the left, a petrophysical vertical 2D section of a Canadian mine model extracted from complete 3D mine model including ore bodies, tunnels and stopes. Table on the right, illustrates the elastic properties of different rock types associate with the mine model on the left.

Figure 2 Snapshots of scattered seismic wave for P and S wave. On the left, model represents orebodies hosted in gneiss and norite background. On the right, parts of orebodies are mined out and remaining voids are backfill cemented.

Modeling results in figure 2 clearly show the complexity of the propagating waves in mine models. For those models with a central source frequency below a few hundred hertz, the propagated waves do not show significant changes in polarity of first arrivals, although their travel times are affected. However, at frequencies above 500 Hz, energy is more scattered and amplitude variation is more significant. Also at some locations the presence of shadow zone is observed. Moreover, the cemented backfill region, a low velocity region, has trapped the energy and this effect is more dominant for S-waves.

Conclusions

A homogeneous velocity background model is inaccurate in deep mines due to the presence of very strong elastic contrasts. This very heterogeneous medium results in a complexity of wave propagation with variations in amplitude, travel time, and phase. The significance of these effects strongly depends on the size, shape, petrophysical properties and the frequency content of seismic source. The modelling results verify the amplification effects at regions with high V_p/V_s ratio (such as voids or cemented backfill) for both P and S wave amplitudes. Sources of higher frequency content displayed changes in polarity and/or creation of shadow zones. The observed complexity of the wave propagation suggests the necessity for further consideration of such effects in the determination of focal mechanisms and full moment tensor inversions.

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References

- Bohlen, T. [2002] Parallel 3-D viscoelastic finite difference seismic modeling. *Computers and Geosciences*, **28** (8), 887-889.
- Gharti, H.N., Oye, V. and Roth, M. [2008] Traveltimes and waveforms of microseismic data in heterogeneous media. *78th Annual International Meeting, SEG*, Expanded Abstracts, SEG, 27.
- Robertsson, J.O. [1996] A numerical free-surface condition for elastic/viscoelastic finite-difference modelling in the presence of topography. *Geophysics*, **61**(6), 1921-1934.