Real time seismic roof condition mapping ahead of longwall caving

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Content

• Why we do this

• Principles – seismic tomography

• How we did

• What we have achieved

• Future work
Longwall coal mining

Mine longwall plan

A typical panel: 300 by 3 km

Roof caving
Looking along panel (A)
Looking side on to panel (B)

Mining face

3-4.5 m
Why we do it?

- Mine risk management and production control
- More resource release
- Assistance in LW automation

Pillar size: ~150,000 m³
Reduced by 5% → increase $1 M

Roof problems can cause days of production loss for a longwall coal mine.
Objectives

To develop real-time seismic tomographic methods for roof condition mapping ahead of LW face using shearer as a source, and provide coal mines with a new capability to visualise roof conditions ahead of and at the longwall face at same time.
Principles – seismic tomography

Crosshole seismic tomography

\[
\delta t_{ij} = t_{ij}^{\text{Obs}} - t_{ij}^{\text{Cal}} = \int_{L_0[S_0(r)]} \delta S(r) dl
\]

\[
\delta t_{ij} = \int_{L_0[S_0(r)]} \delta S (r) dl = \sum_{k=1}^{K} \delta S_{ijk} l_{jk}
\]

\[
\delta T = L \times \delta S
\]
Parameters that may affect seismic velocity

Stress, geological or rock anomalies can be inferred from velocity variation

- Seismic velocity
- Stress concentration
- Geological structure
- Rock damage
Advantages of using shearer as a source

- Real-time mapping
- Prediction 0-300m ahead of mining
- No interference to production
- Information of a large area
- Free seismic source
- Can be integrated into longwall automation system and other visualisation software
Challenges – Questions to be answered

- Does shearer cutting generate seismic energy strong enough to be observed by geophones along the gateroads?
- What are the characteristics of seismic signals and can seismic arrival times be reliably determined?
- Can real-time data processing and result visualisation be achieved?
- Which geophone installation method is more suitable for this application?
Phase I: 2006-2007, ACARP C15023
Objectives: To investigate the strength of seismic signals from the shearer cutting and cost-effective geophone installation method.

Phase II: 2009-2010, ACARP C18018
Objectives: To develop IS geophones and get Certificates.

Phase III: 2012-2014, ACARP C21020
Objectives: Integration seismic tomography using IS geophones with LASC server and underground trials.
Phase I – Experiment at Beltana Mine
Investigation of geophone installation

Geophone locations

In a borehole

Borehole installation

On roof bolt

On dynabolt
Seismograms during production

Seismograms at maintenance time

Using cross correlation techniques the arrival times can be reliably determined!
1. The seismic signals from shearer cutting are strong and can be reliably observed by geophones located more than 300m from the source.

2. The dominant frequency of the shearer signals is 40-50 Hz and their arrival times can be accurately determined using cross-correlation method.

3. Borehole geophone installation is the best option as it acquired seismic signals with a good signal-to-noise ratio.

Conclusion: Real-time roof condition imaging ahead of the face can be achieved !!!
New safety police – bad news!

The passive geophones previously used underground in coal mine are not recognised to be intrinsically safe (IS) in Australian coal mines.

Geophone without an IS certificate cannot be used in ERZ zone near the working face.
Phase II – IS geophone development

- Passive seismic geophones are now required to have IS (intrinsically safe) approval before they can be deployed underground.

- At present there is no IS geophone on the market in Australia.

- IS geophones from South Africa and Canada must obtain certificate before they can be used in underground coal mines in Australia

Objectives: Design and certification of IS geophones for Australian coal mines
Geophone structure: a moving-coil and a fixed magnet.

The relative movement between the magnet and coil produces a voltage across the coil terminals.

The design approach was to make application conditions as flexible as possible while satisfying the standards:

IEC 60079.00
IEC 60079.11
Phase II – IS geophone development
Laboratory tests on sensitivity

Results:

• Over-voltage/temperature tests
• Current injection tests
• Vibration table (10-500 Hz) test
• Geophone comparison test

• The sensitivity of the original geophone is maintained
• No unsafe voltage was observed on outputs
The geophones have been granted certification IECEx SIM 10.0011X and are commercially available in Australia from Holville Pty Ltd.
Phase III – Technology integration and field trials

Objectives:

1. Demonstration of CSIRO seismic tomography techniques for real-time roof condition mapping,

2. Field test of the IS geophones,

3. Test of the efficiency of mine underground communication system for extraction of the shearer position from the LASC server for tomographic mapping and visualisation.
Phase III – Technology integration
Field trial at Grasstree Mine

ACARP C21020 Grasstree Trial Proposed Schematic

- LASC System Primary Server
- LASC System Backup Server
- Visualisation & Processing Laptop (ACARP C21020)
- Flameproof Enclosure (in NRZ)
- IS Geophone Array (Approaching ERZ)
- Above Ground
- Optical Fibre Link to Underground
- IS Barrier
- Data Logger
- 240V Mains Power

Data Logger IS Barrier

Flameproof Enclosure (in NRZ)
Phase III – Technology integration
IS geophone locations

Mine plan and geophone array

Geophone locations along B HDG
Phase III – Technology integration
Underground seismic data acquisition
Phase III – Technology integration
Tomograms

Tomogram for 1666m
Generated at 2014-04-10 04:55:00

Tomogram for 1664m
Generated at 2014-04-10 06:58:00

Tomogram for 1665m
Generated at 2014-04-10 05:40:00

Tomogram for 1663m
Generated at 2014-04-10 10:03:00

movie
Phase III – Technology integration
Conclusions

1. IS geophones are sensitive enough for LW seismic tomography,

2. Integration of the seismic tomographic technology with the LASC server is successful. The shearer position can be reliably obtained from the server,

3. Real-time tomographic images of roof conditions ahead of the face, against each return of the shearer cutting, were successfully obtained.
Two potential concerns were raised by mine engineers:

1. Geophone cable relocation issue,
2. Power supply issue.
Objectives: To integrate seismic tomographic technique with the LVA software, and to provide coal mines with a new capability to visualise roof conditions ahead of and at the longwall face at same time.
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