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Geomechanical effects of stress shadow created by large-scale destress blasting

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ABSTRACT

This study aims to determine if large-scale choked panel destress blasting can provide sufficient beneficial stress reduction in highly-stressed remnant ore pillar that is planned for production. The orebody is divided into 20 stopes over 2 levels, and 2 panels are choke-blasted in the hanging wall to shield the ore pillar by creating a stress shadow around it. A linear-elastic model of the mining system is constructed with finite difference code FLAC3D. The effect of destress blasting in the panels is simulated by applying a fragmentation factor (α) to the rock mass stiffness and a stress reduction factor (β) to the current state of stress in the region occupied by the destress panels. As an extreme case, the destress panel is also modeled as a void to obtain the maximum possible beneficial effects of destressing and stress shadow. Four stopes are mined in the stress shadow of the panels in 6 lifts and then backfilled. The effect of destress blasting on the remnant ore pillar is quantified based on stress change and brittle shear ratio (BSR) in the stress shadow zone compared to the base case without destress blasting. To establish realistic rock fragmentation and stress reduction factors, model results are compared to measured stress changes reported for case studies at Fraser and Brunswick mines. A 1.5 MPa immediate stress decrease was observed 20 m away from the panel at Fraser Mine, and a 4 MPa immediate stress decrease was observed 25 m away at Brunswick Mine. Comparable results are obtained from the current model with a rock fragmentation factor α of 0.2 and a stress reduction factor β of 0.8. It is shown that a destress blasting with these parameters reduces the major principal stress in the nearest stopes by 10–25 MPa. This yields an immediate reduction of BSR, which is deemed sufficient to reduce volume of ore at risk in the pillar.

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1. Introduction

1.1. Overview of strainbursts and destress blasting

Rockbursts are seismic events where the rock suddenly and violently fails in a brittle manner after being strained beyond its elastic limit. Brown (1984) categorized rockbursts based on two underlying mechanisms. On one hand, strainbursts are caused by high stress due to the presence of mine openings and the readjustment of stresses due to excavation, with event Richter magnitudes ranging from −0.2 to 3.5 (Ortlepp, 1992). On the other hand, fault slip bursts are caused by a violent renewed movement along an existing fault, with Richter magnitudes ranging from 2.5 to 5. Fault slip bursts can be mining induced, where the triggering factor for the fault slip is stress readjustment along the fault due to mining activities.

The subject of this paper is destress blasting, which is a strainburst control technique. Ortlepp (1992) categorized strainbursts based on their source mechanism, presented in order of event Richter magnitude: superficial spalling (−0.2 to 0), face buckling (0–1.5), pillar or face crush (1–2.5), and shear rupture through an intact rock mass (2–3.5). Contributing factors to the occurrence of strainbursts are high stress, stiff strata, rapid mining rate, and large excavation area. More recently, Sainoki et al. (2016) demonstrated that the fracture network significantly alters the stress state, generating burst-prone conditions.

Rockburst risk and rockburst damage can be reduced with the following methods. The first is by reducing the mining rate to limit the energy release associated with each mining step (Mitri et al., 1999). The mining sequence can also be adjusted such that the

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stress concentration in remnant ore pillars is minimized, or the volume of ore at risk is minimized (Shnorhokian et al., 2015). Afterwards, the damage caused by rockbursts to mine openings can be mitigated with the use of dynamic rock supports, shotcrete, straps, and wire mesh. Finally, in the case where high energy release per mining step is unavoidable, as is the case with deep mining, ground preconditioning techniques such as destress blasting and destress slotting can be used (Mitri, 2001).

When performing destress blasting, explosives are used to fracture the rock. This lowers the stiffness and releases the strain energy stored in the blasted region. This technique can be directly applied to the rock in the face to be extracted such as in drift development and crown pillar destressing in overhand cut-and-fill mining. It can also be applied to panels near the zone to be mined to create a stress shadow as illustrated in Fig. 1. The former technique was applied at Galena Mine (Boler and Swanson, 1993), Bloyvooruitzicht Mine (Lightfoot et al., 1996), Western Deep Levels South Mine (Lightfoot et al., 1996), Macassa Mine (Hanson et al., 1987) and Campbell Mine (Makuch et al., 1987) with mixed results. The latter technique was applied to Star Morning Mine (Karwoski and McLaughin, 1975), Fraser Mine (Andrieux, 2005) and Brunswick Mine (Andrieux et al., 2003; Andrieux, 2005). Section 1.2 discusses these case studies and their findings.

1.2. Review of destress blasting case studies

Destress blasting or preconditioning of ore was applied at Galena Mine (Boler and Swanson, 1993) after the crown pillar decreased to critical height of 10–20 m or once the arrays of microseismic accelerometers detected an increase in seismic activity. A 21 m overhand pillar was directly destressed with 125 kg of explosives across eight 10 m blastholes and three 4 m blastholes. The stress change was monitored with 8 borehole pressure cells in the footwall. The detected stress drop was only in the order of 0.1 MPa and hence was considered as measurement noise. A numerical modeling back analysis concluded that an 80% drop in pillar stiffness would be required to destress the pillar to pre-mining stress levels. Based on the measured stress drops, the stress change in the pillar was deemed insignificant.

At Bloyvooruitzicht Mine (Lightfoot et al., 1996), continuous destressing of the mining face was implemented in the mining cycle with good results. The rock 4 m ahead of the face was preconditioned with 10 m-long 76 mm-diameter holes. In this case study, 80% of the blasts had an expected seismic efficiency of 1%–2%, with 2 blasts triggering seismic events of magnitude 2.1. Migration of seismic events away from the preconditioned zone indicated a stress transfer away from the mining face. Overall, the face advance rate was increased by 40%; and based on seismic data, the preconditioning program was deemed successful. Western Deep Levels South Mine also employed this technique, with drift convergence data showing an increased rate of inelastic drift closure near the pre-conditioned face.

At Macassa Mine (Hanson et al., 1987), destress blasting was conducted once the crown pillar attained a critical height of 18 m. The pillar was destressed with a line of destress holes in the mid plane of the pillar. Most post-blast seismicity occurred in the pillar, but convergence monitoring indicated only partial destressing.

Similarly, at Campbell Mine, the 4.5 m crown pillar was destressed with 45 mm holes, spaced 1.4 m over the 45 m stope strike, and drilled to within 1.5 m of the overlying drift. The sill pillar above the level was also destressed, with 6 m-long 45 mm-diameter holes, spaced 1.4 m over 25 m. The blast was followed by increased micro-seismicity and rockbursts in the drift and sill pillar itself.

As opposed to direct ore preconditioning, panel destressing consists of blasting relatively large volumes of rock (>10,000 tonnes) in the hanging wall of the orebody, such that the ore to be mined in bulk lies in the stress shadow of the destress panel. In this case, panel destress blasting aims to reduce the risk of rockbursts by reducing the magnitude of the major principal stress in the ore to be mined. This strategy has been applied to Star Morning Mine (Karwoski and McLaughin, 1975), Brunswick Mine (Andrieux et al., 2003; Andrieux, 2005) and Fraser Mine (Andrieux, 2005). The latter two applications were deemed successful based on recorded stress changes, seismicity, and measured displacements.

A comparison between large-scale (<10,000 tonnes) direct destressing and panel destressing was conducted at Star Morning Mine (Karwoski and McLaughin, 1975). The sub-vertical, narrow ore vein is mined with overhand cut-and-fill. A destress blasting trial was done in two adjacent stopes, totaling 80 m in length and 24 m in height. For one stope, destress blasting was conducted in the ore, while in the other stope, it was conducted outside the ore (to create a stress shadow). The 100 mm-diameter holes were fanned parallel to the orebody from the crosscut to the ore vein, with a toe spacing of 2–3 m. Satisfactory results were obtained when destress blasting was conducted inside the ore, based on monitoring of seismic activity during ore extraction.

In the case of Fraser Mine (Andrieux, 2005), a 10,000-tonne choked destress blast was fired on December 24, 2001. The level where the destress blasting took place was exploited with overhand cut-and-fill. Based on numerical modeling, the sill pillar was expected to fail when one or two cuts remained, and the mining rate was slow due to increased seismic activity as the sill pillar became thinner. The objective of the destress blasting was to fracture the hanging wall and deflect high mining induced stress away from mining activity. The extraction of the next few cuts would therefore be facilitated, nonetheless, with the expectation that global failure of the hanging wall would be accelerated, a choked panel destress blasting was attempted. The panel being destressed was 18 m high, 27.5 m wide, and 3 m thick. The targeted mass was 10,075 tonnes. Two parallel rows of holes were fanned

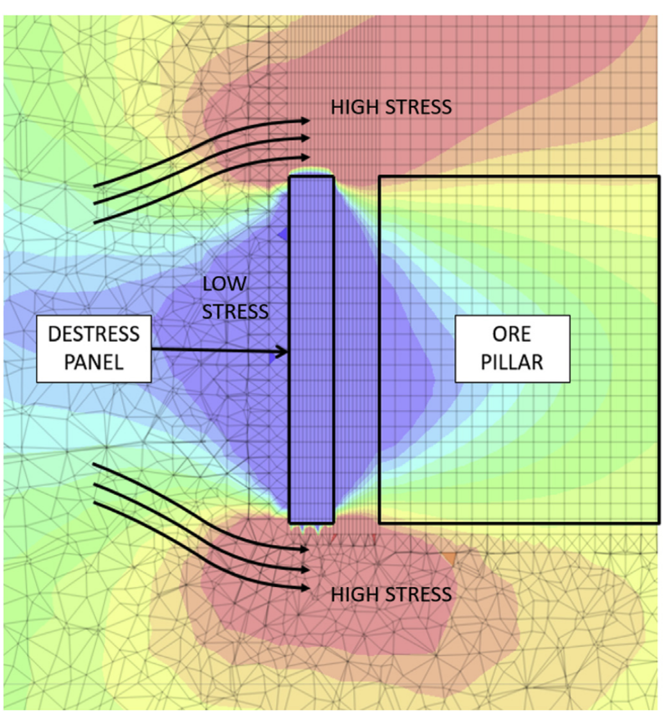

Fig. 1. Example of a destress panel for the creation of stress shadow in the pillar.

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