A New Technology for Measuring Blast Movement

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ABSTRACT

The movement of ore within a blast can have significant economic impact on open pit metal mines. The deposits are often heterogeneous with valuable mineralization disseminated throughout the planned mining blocks and benches. Blasting of these blocks is necessary to fragment the rock mass and loosen the resulting muckpile for efficient excavation however blasting causes movement of the rock and this is detrimental to the accurate delineation of the ore and waste regions within the resulting muckpile. The consequences can be ore loss (the ore moves to a region marked as waste and is discarded) and dilution (waste is miscategorised as ore and sent to the concentrator). If the movement can be accurately measured, ore loss and dilution can be minimised and significant increase in profit can be realised.

Various methods have been used to assess muckpile movement, including poly-pipe, sandbags and magnets but these have been either inaccurate or impractical.

The Julius Kruttschnitt Mineral Research Centre, JKMRC, has developed an electronic Blast Movement Monitor (JKBMM) that provides accurate three-dimensional movement vectors following a production blast. From this information, the ore block boundaries in the blasted bench can be adjusted to compensate for the measured movement and ore recovery can be optimised.

Orica Mining Services commissioned the JKMRC to undertaken two muckpile movement trials at gold mines in Papua New Guinea and North Queensland in 2004. Blast patterns at each were fairly typical for open cut gold mines with powder factors of 0.5 kg/m^3 and 0.8 kg/m^3 in 6 m and 10 m benches respectively. The direction of movement was typically perpendicular to the initiation timing contours as expected from blasting theory, however there are exceptions under certain circumstances close to the blast boundaries and close to the centre of a "V" initiated pattern. Horizontal movement for the low powder factor blasts was up to 4 m, depending upon the distance from the centre of the "V" and 4 – 8 m for the higher powder factor blasts. Vertical movement was up to 2.5 m.

INTRODUCTION

Orica Mining Services commissioned the JKMRC to use their Blast Movement Monitors (JKBMMs) to measure movement within blasts at two gold mines.

The JKBMM provides a reliable and timely method of measuring blast movement compared to more traditional means and can provide blast movement vectors within a few hours of the blast. Traditional methods require excavation and exposure of the targets to measure their location, by which time a portion of the blast may have already been excavated.

Coupled with the ability of electronic initiation systems to control movement and even produce segregated ore and

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waste parcels within blasts, the JKBMMs offer mine operators the most precise control over blast dilution ever achieved.

TRADITIONAL MEANS OF MEASURING BLAST MOVEMENT

Understanding movement of material within a blast has always been of interest to mine operators where there is no clear visual distinction between ore and waste. The primary need is to ensure waste, high grade and low grade material is correctly identified and transported to the correct destination. Waste inadvertently trucked to the mill wastes processing capacity and increases processing costs, while ore trucked to waste dumps results in a loss of revenue and reduces the profit.

While detailed calculation of the value or cost of ore loss and dilution is beyond the scope of this paper, the potential losses to operators who do not correctly identify post-blast boundaries can be of the order of hundreds of thousands of dollars per blast.

Traditional methods of measuring blast movement have involved burying visual markers such as chains, poly pipe or sandbags in the blast and attempting to locate them as excavation proceeds. These methods are easy to implement but suffer the disadvantages of low recovery rates and time consuming surveys. If the markers are recovered, the movement information may be too late to be useful.

The University of Nevada, Reno developed a remote magnetic sensing method to detect buried magnets in three dimensions (Harris, 1997). To date, these have not been commercialised.

JKBMMS

The JKBMM is a directional transmitter housed within a protective shell. In its present form, the transmitter has sufficient power to run for 8 hours after assembly although a model which will "sleep" for up to 3 months has been prototyped.

BMMs are placed in separate holes drilled between blastholes and are held in place by drill cuttings or stemming. They can be installed at precise horizons throughout a blast, thereby measuring movement at different levels within the blast mass. The horizontal placement of BMMs is limited only by proximity to adjacent blastholes and proximity to each other. Experience to date indicates that they should be at least 10m from each other, to avoid overlapping signals and if the current BMMs are located closer than about 1.5 m from a 115 mm blasthole, some failures will occur.

Method of Application

Before the blast, the installation location of the BMMs is selected according to the desired outcome. BMMs were evenly spread across the pattern in the blasts described in this paper, although it would also be possible to locate BMMs on a known ore and waste boundary or any other point of interest within the blast.

Holes are drilled at the selected locations and these holes are accurately surveyed for easting, northing and collar RL. Immediately before the blast the BMMs are assembled and installed at the desired RL within each hole and the holes are stemmed.

After the blast, BMMs are located using a directional receiver which is used to "home" on the signal produced by each BMM. Once the horizontal location of the JKBMM is pinpointed, the signal strength is recorded to determine the depth of the BMM below the surface. Location of 12 BMMs takes about one hour.

Once the final positions are surveyed it is possible to calculate the three dimensional movement vectors of the BMMs in less than one hour (for 12 BMMs). These results can then be presented graphically on top of the blast plan to predict the movement of the boundary or points of interest.

CASE STUDIES

Project One

Thirty six BMMs were deployed across 3 blasts at a gold mine using 171 mm holes to blast a 6 m bench using a 4.7 m x 4.1 m pattern. The powder factor of the blasts was in the range of 0.47 to 0.50 kg/m^3 of wet hole emulsion based explosive. All BMMs were placed at a nominal depth of 3 m, being half the height of the bench. All three blasts were initiated using 25 ms x 65 ms surface delays in a “V” or “Diamond Centre Lift” pattern.

All 36 BMMs were detected. The direction of movement was typically perpendicular to the timing contours (Figure 1), but tended to be more variable close to the centre of the “V”. The average horizontal movement in the body of the blasts was around 4 m. Less horizontal movement was measured in the power trough and close to the centre of the “V”.

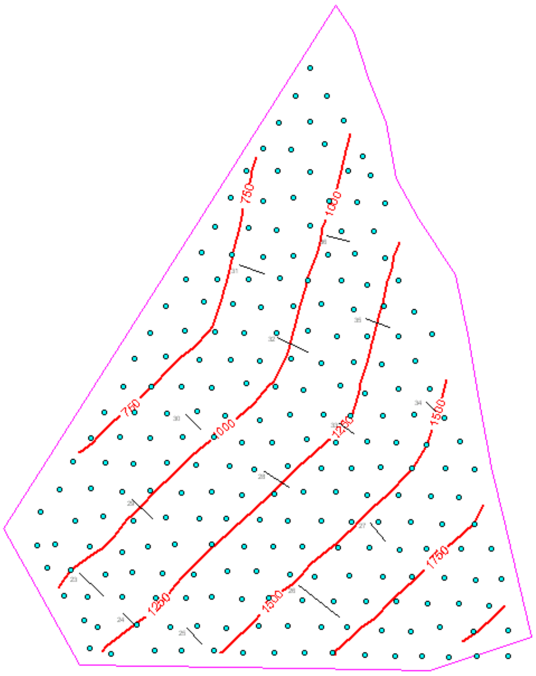

Figure 1 - Blast plan of design timing contours with measured movement vectors

The average horizontal movement of BMMs grouped by their position in the blast is represented graphically by wedges in Figure 2. The length of each wedge is the arithmetic average of the magnitude of the measured movement vectors. The angular spread of each wedge (from zero) is the arithmetic average of the absolute value of angular differences between each measured vector and the design angle of initiation at that point of the blast.

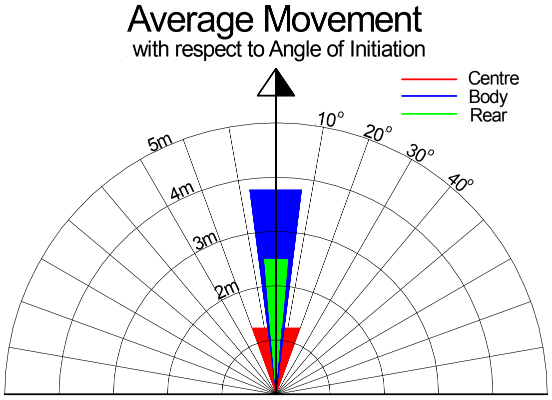

Figure 2 - Average horizontal movement of BMMs grouped according to their location in the blast

The chart of average movement shows that movement vectors are largest and more predictable in the body of the blast. Conversely, movement at the centre of the blast is smaller in magnitude and more variable in direction.

The apparent relationship of horizontal movement to location in the blast was also examined using a histogram of the horizontal displacement data (Figure 3). The distribution appears to be tri-modal, with peaks at approximately 1.5 m, 2.0 m and 4.0 m. Analysis of the data shows that these peaks are made up of BMMs grouped by their location in the Centre, Body and Rear of the blast. However, the data set is limited and to be confident of this relationship further work is required.

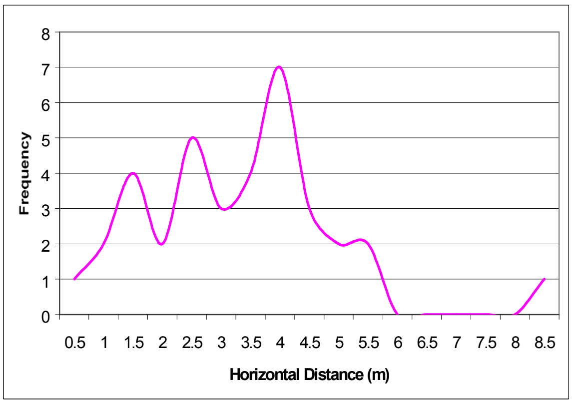

Figure 3 - Histogram of measured horizontal movement of 36 BMMs

The relationship between average vertical movement and location in the blast shows those BMMs in the centre (ie. on the control row) experienced more vertical movement than those in the body of the blast. BMMs in the back rows (ie. in the power trough) actually moved downward, as expected. This data is presented in Figure 4.

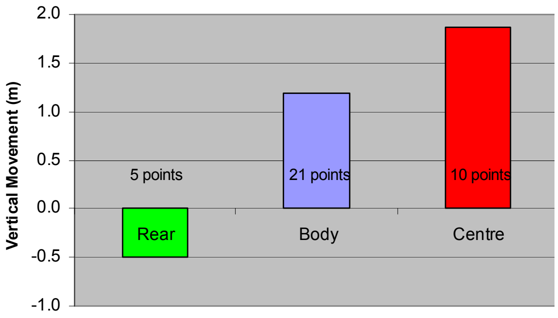

Figure 4 - Average vertical movement of 36 BMMs grouped by location in the blast

Project Two

At another gold mine, 36 JKBMMs were used in 3 similar blasts on a 10 m bench using 115 mm blastholes on a 3.7 m x 3.7 m pattern. The powder factor was approximately 0.77 kg/m^3 of wet hole bulk explosive.

In this case, 27 of the 36 BMMs were detected. The losses can be attributed to some BMMs being too close to blast holes combined with the rockmass characteristics. Measured horizontal movement was between 3.6 m and 8.8 m, and vertical movement between 3.6 m down and 3.3 m up was observed.

The observed movements were significantly more than those observed during Project One. This is expected because the Project Two blasts were on deeper benches with higher powder factors and more free faces.

Grouping the measurements by depth of burial shows there is no apparent difference in horizontal movement measured at 4 m depth compared to 8 m depth (Figure 5). This observation may be due to the fact that both levels are adjacent to the explosive column and well away from influences of the top and bottom of the bench and therefore should not be construed as a general hypothesis. Other data suggests direct relationship between horizontal movement and depth but more data is required to quantify this.

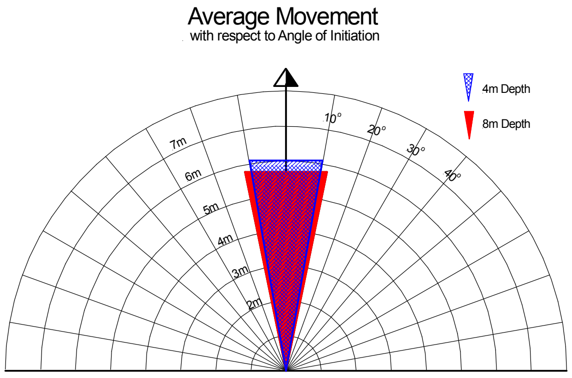

Figure 5 - Average movement of 27 BMMs grouped by depth of burial (13 @ 4m and 14 @ 8m on a 10m bench)

In general terms measured movement was consistent with design predictions in the body of the blasts (ie. away from the control row and blast edges). A tendency for movement to deviate slightly towards the boundary was observed in the monitors located close to blast edges.

Again, a histogram of the horizontal movement data appears to display a tri-modal distribution (Figure 6). However in this project there were not enough BMMs positioned in "centre" and "rear" locations to establish a valid relationship between monitor location and movement. The blast initiation designs were also different for each blast.

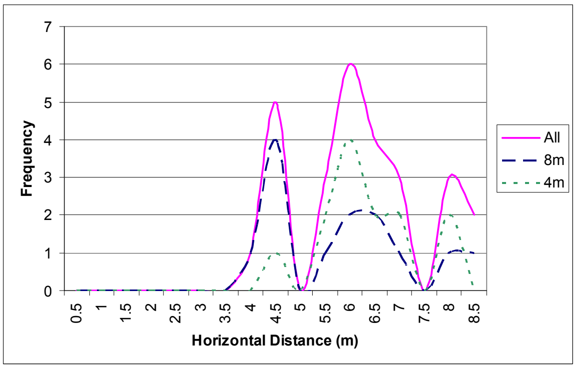

Figure 6 - Histogram of measured horizontal movement of 27 BMMs

CONCLUSIONS

Deployment of 72 BMMs in six blasts has shown the system to be reliable and easy to use, providing timely and useable data to predict blast movement. The measurements to date have shown substantial horizontal and vertical movement in blasts which cannot be ignored when locating ore and waste boundaries post blast.

Measured horizontal and vertical movement within blasts was consistent with expectations. That is, horizontal movement was greatest and most predictable in the body of the blast, and smaller and less predictable in the centre of a "V" or centre lift blast. Similarly, vertical movement was greatest in the centre of the "V", and downward movement was measured in the powertrough. More measurements are required to test the relationship between horizontal movement and depth.

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