Improve Milling Through Better Powder Distribution

by
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INTRODUCTION

Optimization of blasting requires the comprehension of processes including drilling through milling. The author has previously considered the role of powder factor in relationship to downstream processing costs. Recent modeling done by Lownds provides improved prediction of fragmentation based on the distribution and level of blast energy. Many recent studies have indicated improved downstream costs due to higher powder factor. However, changes in powder factor are accompanied by changes in pattern. The purpose is to segregate the effects of higher powder factor from powder distribution. This paper will attempt to use typical Mesabi Range iron ore parameters and costs to illuminate the subject of total process optimization.

Rock Weakening

Evidence is mounting in support of the notion that blasting plays a role beyond simply separating ore from the ground so that excavators may load it. Reports from seemingly dispirit sources have pointed to a pre-conditioning phenomenon resulting from the rock's exposure to the intense shock and gas pressure released during detonation of modern explosives.

- The Corps of Engineers has noticed that jetty stone on the great lakes have shorter life spans since black powder was replaced by higher brisance explosives in the 1950's.

- 'Chilling' and subsequent loss of coal has received much attention.

- Tunneling research has lead to methods that create smooth walls with a minimum amount of damage from blasting.

- Ore processing using autogenous mills have noted that increased powder factors have actually hurt productivity due to the weakening of the larger pieces which act as the grinding media.

The unifying theme in these problems all relate to the 'invisible' fragmentation, called incipient cracks, Griffits flaws or microcracks.

Previous work

Modern comminution theory goes back to 19th century Germany where Rittinger(1867) and Kick(1885) proposed models based on surface area and particle volume respectively. Bond(1951) proposed a third theory of comminution which is still widely used today. King and Schneider(1995) at the University of Utah have very recently demonstrated improved modeling of grinding circuits. Overall blast optimization has more recent roots. MacKenzie(1966) reported on costs in iron ore from drilling through crushing. Udy and Thornley (1977) reviewed optimization through crushing. Gold(1987) tabulated and modeled overall mining cost related to blasting at Fording Coal. LeJuge and Cox(1995) reported overall costs in quarrying. Eloranta(1995) published costs in iron ore from blasting through grinding. Moody et al(1996) related dig times, crusher speeds and particle size to fragmentation in quarry operations. Furstenau (1995) used single-particle roll mill crushing to demonstrate a 10% energy savings in the drilling through grinding process by increasing powder factor by 25%. Recent laboratory work has been aimed at tying mine and processing size reduction to common factors. These efforts include the work of Revnivtsev(1988) who related microcracks from blasting to energy use in subsequent crushing and grinding. McCarter(1996) has quantified blast preconditioning through the use of a ultra fast load cell. Nielsen(1996) has done extensive grinding tests on preconditioned rock and demonstrated changes in Bond work indices of nearly 3 to 1.

Where from here

Current Mesabi Range powder factors are in the range of .5 to 1.0 lbs/LT. A doubling of powder factor is needed to test optimum levels recommended by Russian researchers. (Revnitsev, 1988) To explore higher powder factors, additional drilling will be required since hole diameters are already at 16 inches. Large diameter drills suitable for the iron ore environment are large capital purchases, and hence may not be available for high powder factor tests. Milling tests of increased powder factor are often difficult to conduct when ore blending or segregation issues appear. The overall economics may include wear rates and flowsheet changes requiring new screen sizes and changes in volumes of over and under flow from the new screens that exceed the take away capacity of individual conveyors. For these reasons, it is critically important that reliable models are developed to assure success when flowsheet changes are implemented.

Large, movable crushing plants have been install to capitalize on the low costs associated with conveyor haulage. Cost reductions of an order of magnitude have been achieved. However, movable crushers are expensive and the process does not appear to have the pre-conditioning benefits of blasting. (Nielsen, 1996) A mine that can't afford a $50 million movable crusher may be able to purchase a number of drills for less than $2 million each.

Improved modeling and verification will move forward quickly with the advent of three technologies: drill monitoring, video image size analyzers and better computer modeling. Hundreds of drills are currently in place worldwide. Characterization of the rockmass in itself will not lead to optimization. Digital image analysis also has a large installed base of over 100 on line systems. These two technologies form bookends on the blasting process. Knowing the endpoints will, in turn, make meaningful modeling a reality. The model proposed by Lownds (1998) addresses fragment size and the shock intensity that each parcel of rock received.

Lownds Model

The Lownds model recognizes two zones of fragmentation. Close to the powder column, the energy levels are sufficient to mask existing joint patterns. This zone is modeled using the Person-Holmberg equation. At some greater radius from the powder column, crack formation is dominated by existing joints. Using the joint direction and frequency, the probability of crack extension crossing a joint is calculated.

It was the intention of this study to use the Lownds model. As it turned out, minor modifications that could not be addressed within the time constraints of publishing; caused it to be left out. This model will provide insight into the pre-conditioning (perhaps a new predicted Bond work index?) as well as fragment size.

Bond Equation

The Bond equation was developed in the 1950's for the purpose of designing crushing and grinding circuits. Though recent developments have rendered it obsolete, there exists a vast database of rock properties based on the Bond Work Index (Wi).

$W = 10\ Wi(1/P^{.5} - 1/F^{.5})$

where:
W = work input in kW-hr/ton
Wi = work index for rock type in kW-hr/ton
P = product size (80% passing) in microns
F = feed size (80% passing) in microns

Methodology

By dollarizing various blast fragmentation options, it is possible to compare D&B costs to the balance of the work remaining in crushing and grinding using actual costs and Bond's third equation.

For fixed powder factors, vary diameter, burden and spacing where B=S
1) Calculate drill and blast cost using typical Mesabi Range values
2) Calculate mean size using Kuznetsov
3) Calculate characteristic size
4) Calculate 80% passing size
5) Plot P80 vs. D&B$/LT
6) Add actual Mesabi Range costs
7) Calculate a modified Bond Work Index

Kuz-Ram Modeling

The basis for the Kuz-Ram model is well documented.(Cunningham,1983) The inputs for this exercise are:

$X50 = A\ [Vo/Qt]^{0.8}\ Qt^{1/6}$

Where:
X50 = Mean size
A = Rock factor (8 assumed)
Vo = Volume of rock
Qt = Mass of explosive

Xc = X / [ln (1/R)]1/n

Where:
Xc = Characteristic size (63.2% passing size)
X = Screen size
R = Proportion retained on screen
n = Uniformity Index (1.2 assumed)

Assumptions

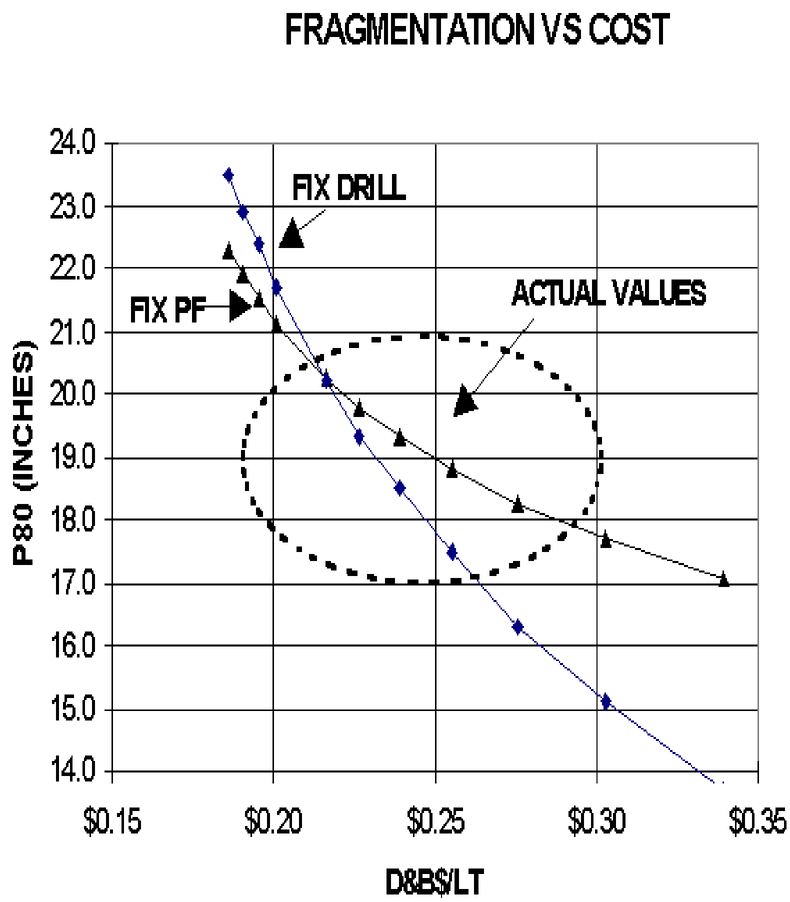
Pattern design includes parameters typical of Mesabi Range iron ore blasts:

Bench Height BH = 40 feet
Sub Drilling Sub = 3 feet
Stemming ST = 15 feet
Powder factor PF = .77 equivalent anfo lbs/ long ton
Rock density RD = 200 lbs/cubic foot
Powder density PD = 1.32
Relative weight strength RWS = 92 (ANFO = 100)
Drilling cost DC = $5.00/foot (constant for all hole diameters)
Powder cost PC = $0.17/lb
Surface cap SC = $3.00
Booster BSTR= $4.00
Downhole cap DH = $5.00

Energy factor is held constant by adjusting the burden and spacing (equal) and the hole diameter. Pattern is held constant in the second case to investigate changes in powder factor(hole diameter). Pattern geometry is converted to costs using the assumed costs. The modeled costs are then referenced to actual costs which are matched to sizing from video images of run of mine rock taken at the primary crusher. The locus of size/cost points are represented as an oval-shaped range.

Results

The attached graph compares Kuz-ram modeled costs to actual field experience. The y-axis has customary p80 values in inches. The x-axis is unusual in that the blast parameters are converted to modeled drill and blast costs. The actual costs are summarized by an oval. One might conclude that the pursuit of finer fragmentation is achieved most economically by maintaining the same drill pattern and increasing the powder factor. However, the model has a fixed cost for powder (so higher density products are not comprehended in cost) and the cost per foot for drilling is held constant (so even if bits larger than 16-inches were available, the higher cost is not comprehended).



Efforts to actually tie drill and blast costs to milling via the Bond equation are not published. Since shock intensity was not ultimately available, no comments could be made concerning the new work index resulting from changes in pattern or powder factor

Conclusions

At this point, it is inconclusive whether better distribution or more energy is a more economical choice in the pursuit of lower overall costs. The two curves may form the boundaries of the cost trend. In the real world, there not larger bits for hard rock mining, nor are there blasting agents of ever increasing density that would allow infinite flexibility in designs. Finer fragmentation will be a result of changes in both distribution and powder factor.

Refinement of this Kuz-Ram model could provide a clearer picture. However, the benefits of higher energy levels in the drill and blast process appear to be greatest in the pre-conditioning of the rock, not the physical size. For this reason, modeling should comprehend shock intensity to model rock weakening as well as fragment size.

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