Characterization of the Pre and Post Blast Environments

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Abstract

We often hear that, "Blasting was an art, but now blasting is now a science". 'Scientific' blasting implies that we have quantified and reproducible measurements of the feedstock and product of the blasting process. However, the industry's reluctance to adopt two key technologies, drill monitoring and optical size analyzers, sheds doubt on the claims of scientific blasting.

Blasting is but an early step in a manufacturing process. Consider an automotive plant that didn't monitor tolerances of incoming parts or outgoing vehicles. It is unimaginable. Yet, this is the rule rather than the exception in our industry.

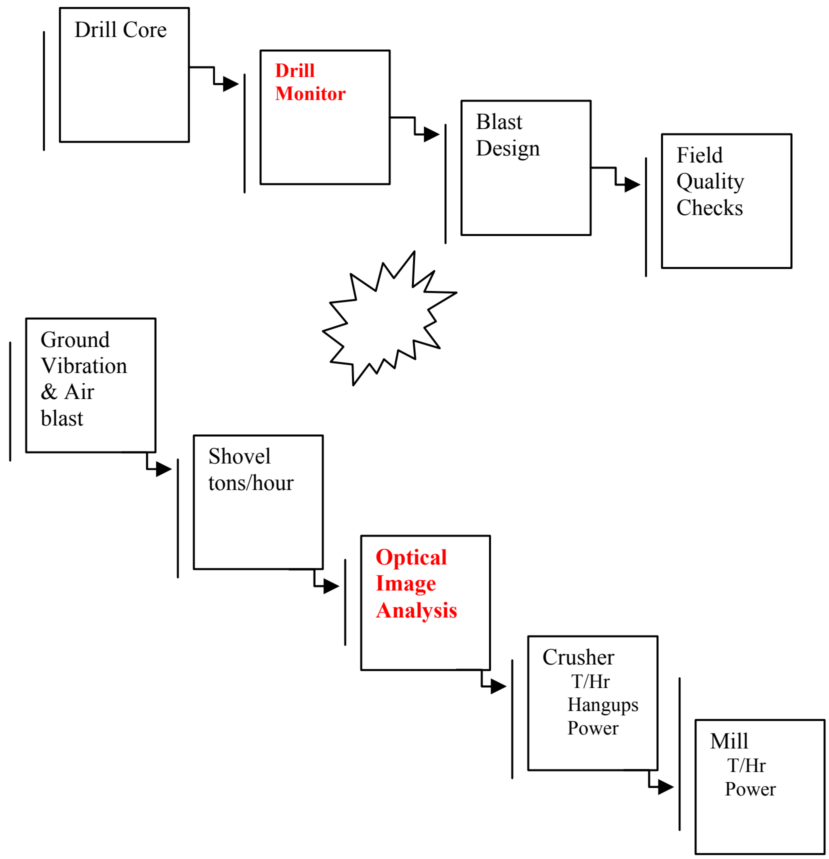
Past problems in comprehending these technologies has resulted from the lack of an integrated approach to comprehending pre-blast, blast and post-blast data. This paper will review published correlation efforts for both drill monitoring and optical sizing. It will also use new data to investigate the relationships.

The closest measures that form 'bookends' to the blasting process are drill monitoring and optical size analyzers. Previously published work by: Thompson, Yin, Vynne and others; have relied on assorted known parameters against which drill monitoring data was compared. This paper follows a technique devised by Dance in which relies on simple measures of resulting size profiles. Rather than to use interpolated or modeled estimates to fill in size fractions that lie below the resolution of the lens used in optical sizing; Dance simply tracked 3 three key size fractions that lay within the resolvable range of the lens.

Simple measures that involve little adjustment, are not, themselves subject to calibration errors. Measures of drill core properties have been difficult to correlate to drill monitoring. Clearly, drill monitoring and optical have not been brought into the mainstream of drill and blast technology. Although, a rational database for blast optimization must include additional information; optical sizing and drill monitoring should form the centerpiece.

Introduction

In 1996, I presented a discussion of rockmass characterization factors in a paper named, Geologic Data for Blasting". In the intervening seven years, progress has occurred in pre-blast rockmass characterization. The installed base of drill monitors and of on-line, optical size analyzers has swelled. Rapid improvements in hardware and enhanced software have made both technologies affordable and reliable. Unfortunately, staffing levels have been decreasing; leaving departments shorthanded in their efforts to really utilize the data from size analyzers or drill monitors. As a result, the full benefits of these technologies remain unfulfilled.



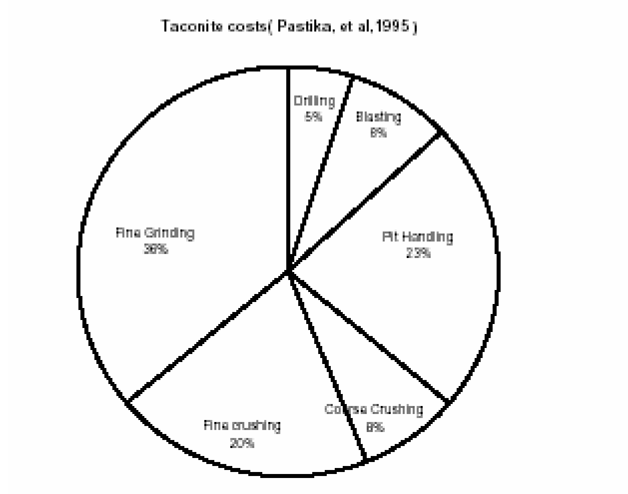
The parameters needed for blast design and evaluation are slowly becoming recognized. Continued refinement of measuring devices and interpretation software has resulted in reliable and affordable systems. However, those operations that have invested in hi-tech systems have generally not reaped the rewards. The reason is that blast designers are now awash in data while remaining short of information.

Researchers have attempted to 'calibrate' drill monitoring data to geologic horizons. In coal, this has been a successful endeavor. In metal mines, however, identification of horizons is not sufficient.

Researchers need to broaden their view of the fragmentation process.

The key parameters are drill monitoring and optical image analysis efforts should focus on finding clues in the drilling data that foretell fragmentation.

The importance of a sound evaluation system cannot be overstated. It is unfortunate that mines have not recognized the value of creating a reliable scorecard for blast performance. The payback for blast optimization has been documented to be in the order of tens of millions of dollars. In taconite operations, D&B operations account for about 13% of concentrate cost. (Pastika, 1995) The investment to improve D&B is gauged by that cost. Meanwhile, the cost to crush and grind in taconite represents 58% of concentrate cost. Those areas benefit from the attention (& budgeting) they receive, as a result. Until upper management recognizes the dramatic effects of blasting on subsequent milling – the development of a comprehensive blast evaluation system will languish.



Yin's (2000) work has focused on reducing the voluminous data generated from drill monitoring at the Minntac Mine. The good news is that those downstream measuring technologies are, not only developed, but are in place at many mines today. GPS-capable mines tag coordinates to shovel and crusher productivity and crusher power. Those using on-line optical size analyzers, such as the Wipfrag system, have size distribution tied back to shovel locations.

The volume of data generated in these downstream operations is large. As a result, the typically small staffs at operating mines are overwhelmed by data. The simplification that Dance (2000) reported at Highland Valley Copper makes interpretation a manageable task.

It is appropriate to reflect on the purpose of each step in the fragmentation/comminution process. Drilling is done to place blasting agents. Creating drillholes should not be viewed as an obstacle to mining, but rather an opportunity to measure the geomechanical rock properties in advance of downstream operations. Blasting is done to facilitate loading crushing and grinding. Since crushing and grinding is such a large cost area, that data must be part of the drill monitoring calibration.

Current efforts at interpreting drill monitoring have outrun the ability to measure blast outcomes. Subtle changes in lithology, field controls, blast orientation to key geologic features and explosive and accessory performance; result in widely varying fragmentation results. Until actual data on blast performance are available, drill monitoring benefits will be limited.

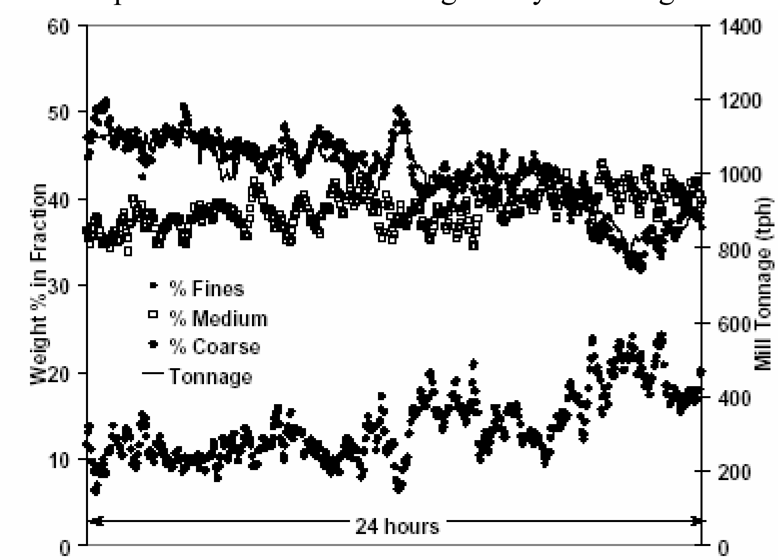
Blasting continues to be viewed as a necessary evil by many upper-level mine managers (Peterson, 2001). This view, however, is held at a considerable expense to mine and mill costs. Blasting has the primary objective of freeing mineral material from the solid earth. Secondary objectives, in metal mines, are to create small fragments to ease handling and crushing costs and to weaken those fragments to reduce milling costs.

This paper will focus on two technologies that the author identifies as critical measurements necessary for optimizing the secondary objectives of blasting. Drill monitoring and optical image analysis afford the opportunity to characterize the pre-blast environment and to measure the resulting size of blasted fragments. The third parameter, rock strength, can be determined by monitoring crusher and mill energy requirements.

Previous Work

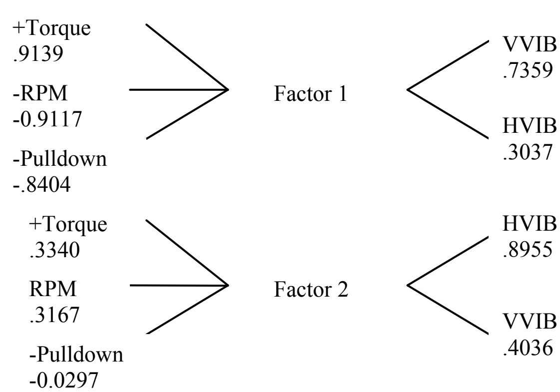
Dance, 2001

Adrian Dance has published a description of the use of an image analyzer at Highland Valley Copper. Ingeniously sidestepping the question of 'invisible fine', he simply uses simplified descriptors; 'fine medium and course' fractions. Since modeling the invisible fines is a somewhat arbitrary exercise, only actually visible fractions are used in the control scheme. This is a good method which is 'results oriented'. If we take that approach to characterizing pre and post blast environments, we can quickly get usable data for process optimization.



Yin, 2000

Yin has used data from Thunderbird-Pacific equipment at the Minntac Mine to develop relationships to interpret raw monitoring data. She concludes "Monitoring has great potential to facilitate drill and fragmentation



optimization through better control and design. Such integration will require expanding and improving the current database and information systems." She has developed two factors and named them: Operating Factor (Factor 1) and Rock Property Factor (Factor 2).

Specific energy has been identified as a useful parameter available from drill monitoring. But, if you give specific energy data to a blast designer; he will not be able to translate that data into real information or knowledge. Yin noted that specific energy data tends to have an excessive amount of noise.

Hendricks, 1992

Using the Aquila™ monitoring system, excellent results in defining geologic horizons have been achieved. Successful discrimination between coal and mudstone is described. He reports that mines have achieved payback in less than one year. He describes a factor called the blastibility index (BI) which characterizes the overall competency of the rock mass. It is interesting that he notes, "most mines over-design their blasts to ensure that hard toe, tight muck and oversize is minimized". BI is also used to estimate ore hardness and grindability. Yet, recent research indicates that under-blasting for milling purposes remains common.

Vynne ,1999

Vynne describes the use of the StrataLogger™ monitoring system at QCM, Minntac and Bingham Canyon. Key reports and hardware architecture are detailed. His focus is on, "1) the movement of the data and 2) software to improve access to the raw data.' He notes that "The mine must make the financial, time and staff commitment following the purchase of the systems to insure that utilization of the data occurs."

Thompson, 1999

Thompson has: compared drill monitoring parameters to geologic horizon, evaluated bit performance and mapped 'hard' and 'soft' zones for the purpose of adjusting powder factor. Specific energy is a key variable at Minntac. Specific energy is calculated:

$$SE = (2PI\ NT)/[R/60PI\ (0.5D)^2] + W/[PI(0.5D^2]$$

Where: SE = Specific Energy (ft-lb/in^2-ft)
N = RPM
R = Drilling rate of penetration or D-ROP (ft/hr)
T = Torque (ft-lb)
W = Bit Load (lb)
D = Diameter (inches)

While Thompson has been cited as the leader in using drill monitoring data, he notes that Minntac, "ha(s) just begun to scratch the surface".

Mill engineers are interested in blasting

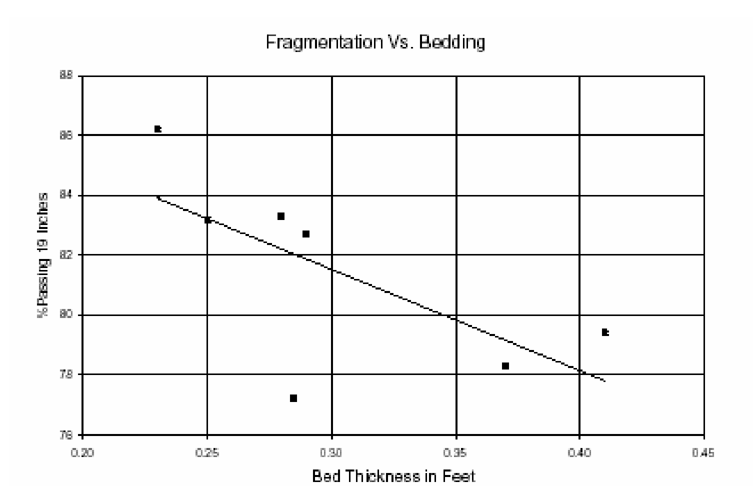
At a recent milling conference, it was made abundantly evident that a great deal of ferment is underway in the SAG mill design. Lifter design lifter angle, mill speed mill load, feed size, grate size, ball size and ball charge weights are being varied.

The following are several of the titles and authors of blast-related papers given at the SAG2001 conference held in Vancouver:

- Optimisation of the Cadia Hill Sag Mill Circuit (Hart)
- Optimization of the Alumbrera Sag Mills (Sherman)
- SAG Milling at the Fimiston Plant (Karageorgos)
- Optimized Iron Ore Blast Designs for SAG/AG Mills (Eloranta)
- The Impact of Feed Size Analysis on the Autogenous Grinding Mill (Bouajila)
- Maximizing Sag Mill Throughput at Porgera Gold Mine by Optimizing Blast Fragmentation (Lam)

Collaboration between drilling and milling people is clearly required. Tapping the current interest in the interactions and effects on their mills can give drill monitoring interpretation a real boost. The following parameters should be compared to the output of drill monitoring:

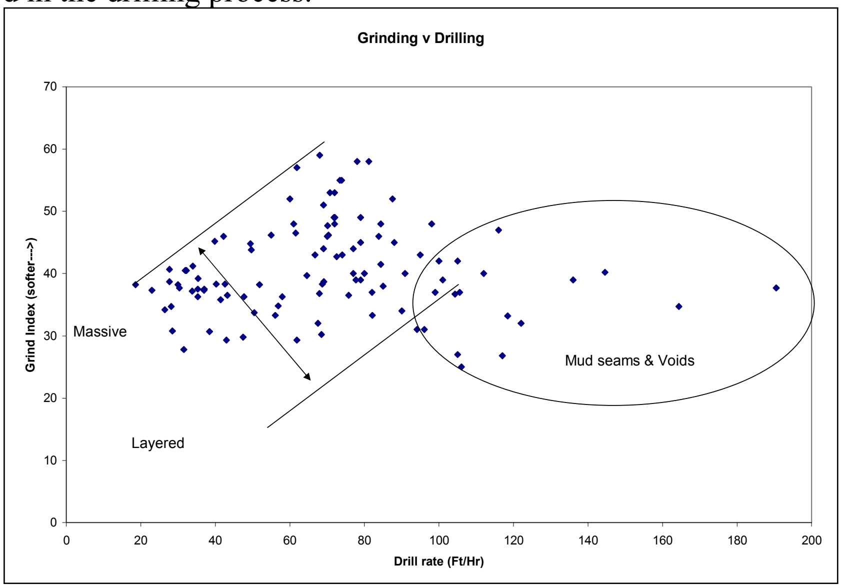
- Crusher speed
- Crusher amps
- Mill throughput
- Mill power draw



Penetration Rate and bed thickness

Penetration rates may not be a useful predictor of mill performance in laminated formations. Where bed thickness is ideal, penetration rates will benefit. Layers that are thick enough to produce large chips while still thin enough to break with the available downpressure make for high penetration rates. Sufficient air volume is, of course, necessary to eject the pieces. This would suggest that a bed thickness slightly below the size of the annular space (between drill pipe and borehole walls) would result in less surface area being created in the drilling process.

However, the microscopic fabric of the formation controls the grindability of the ore. Metal mines often grind to 200 mesh and finer. In taconite, 40 mesh is the approximate halfway point of fragmentation, in terms of energy consumption.



Tracking Material

GPS provides the spatial accounting, starting with drill hole coordinates and ending with trucks dumping in the primary crusher. Bins and stockpiles which are a part of every flowsheet, usually result in a loss of identity of material at this point. Material can still be tracked after commingling by looking at longer time frames. Depending on typical stock/destock cycles; time frames may go to shift, day week or even monthly averages.

The technology for creating data on the pre and post blast environments is sufficiently mature. Where work remains, is in transforming data into information and then turning that subsequent information into knowledge. Every provider of these technologies will attest to the same phenomena. The customer buys the device and expects that the data will directly lead them to improved outcomes. In every case, someone must decide how to react to changes in the output parameters of the device.

Conclusions

1) Efforts to correlate drill monitoring to geologic horizons, compressive strength or specific energy do not offer the payback of correlations to downstream parameters.
2) Image analysis and drill monitoring are maturing technologies that are critical to fragmentation optimization.
3) It is now up to the mine operators to develop control algorithms to make use of drilling and sizing data.
4) Simple, results oriented control schemes, similar to the Dance's model, provide a good example.

References

Bouajila, A., Bartolacci, G., Kock, N., Cayouette, J. and Cote, C., "Toward the Improvement of Primary Grinding Productivity and Energy Efficiency. Part 1; Investigation of the Feed Ore Size Effect" IFAC Workshop, Future trends in automation in mineral and metal processing (MM'2000), Finland 22-24 August 2000, pp 280-285.

Dance, A. 2001, "The Importance of Primary Crushing in Mill Feed Size Optimisation" Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol. 1 pp189- 202

Eloranta, J. W. 1995, The Effect of Fragmentation on Downstream Processing Costs. Proceedings of Explo95 Conference, Brisbane, Qld, Australia, Sept. 4-7, 1995 pp 25-28

Eloranta, J. W. 1996, "Geologic Data for Blasting" Proceedings of the twenty-second conference of Explosives and Blasting Technique, Orlando, Florida, February 4-8, 1996. International Society of Explosives Engineers, Cleveland, Ohio, pp 107-117

Eloranta, J. W. 2001, "Improve Milling Through Better Powder Distribution" Proceedings of the twenty-seventh conference of Explosives and Blasting Technique, Orlando, Florida, January 28-31, 2001. International Society of Explosives Engineers, Cleveland, Ohio.

Eloranta, J. W. 2001, "Optimized Iron Ore Blast Designs for SAG/AG Mills" Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol. 1 pp 262-270

Hart, s., Valery, W., Clements, B., Reed, M., Ming Song, Dunne, R., 2001, Optimisation of the Cadia Hill Sag Mill Circuit Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol. 1 pp. 59 – 75

Hendricks C., Peck J., Scoble M., 1992, "An Automated Approach to Blast Optimization Through Performance Monitoring of Blast Hole Drills and Mining Shovels" 4th High Tech Seminar on Blasting, Nashville, Tennessee June 1992

Hendricks, C., 1999, "GPS Positioning and Equipment Monitoring technology for Blasting Operations" Proceeding of Minnblast99pp.225-238, Duluth, Minnesota, June 1999, available from ISEE, Cleveland, OH

Hendricks, C., Peck J., 1994, "Advanced Technology for Blast Design Execution & Assessment" 5th High Tech Seminar on Blasting, New Orleans, Louisiana, July 1994

Karageorgos, J., Valery, W., Skrypniuk, W., Ovens, G., 2001, "SAG Milling at The Fimiston Plant (KCGM)", Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol I page 109-124

Lam, M., Jankovic, W., Valery, W., 2001, "Maximizing SAG Mill Circuit Throughput at Pogera Gold Mine by Optimizing Blast Fragmentation", Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol. 1 pp271-288

Morell, S. and Valery, W. Influence of Feed Size on SAG/AG Mill Performance, Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, p I-203 - I-214

Paley, N and Kojovic, T., 2001. "Adjusting Blasting to Increase SAG Mill Throughput at the Red Dog Mine". Proceedings of the twenty-seventh conference of Explosives and Blasting Technique, Orlando, Florida, January 28-31, 2001. International Society of Explosives Engineers, Cleveland, Ohio

Pastika et al, 1995, "Improved Fragmentation for Mine Cost Reduction. Proceedings of the 68th Annual meeting of the Minnesota Section of the AIME and 56th Symposium, Duluth, MN pp185-192

Peterson D. J., LaTourrette T., Bartis, J.T., 2001, New Forces at Work in Mining: Industry Views of Critical Technologies ISBN: 0-8330-2967-3, MR-1324-OSTP

Sherman, M, 2001, "Optimization of the Alumbrera Sag Mills", Proceedings of the International Conference on Autogenous and Semiautogenous Grinding Technology held September 30- October 3, 2001, Vancouver, B. C., Canada, Vol. 1 pp. 11 – 30

Simkus, R. and Dance, A., 1998, "Tracking Hardness and Size: Measuring and Monitoring ROM Ore Properties at Highland Valley Copper", Mine to Mill 198 Conference, Brisbane, Australia (AusIMM Publicatio No 4/98), pp. 113 - 119

Thompson, D. 1999, "Modern Drilling and Blasting Technology at the Minntac Mine" Proceedings of Minnblast 99 Surface Blasting Conference pp 77-96, June 7-11, 1999, Duluth Minnesota, Available from ISEE Cleveland, OH

Vynne, J, 1999, "Drill Monitoring Developments and Utilization of the Drill Data" Proceeding of Minnblast99 pp.185-196, Duluth, Minnesota, June 1999, available from ISEE, Cleveland, OH

Yin, K., Liu H. and Yang, 2000, "Extracting information from drill data", Fragblast Journal 4(2000), A. A. Balkema, Postbus 1675, Rotterdam, Netherlands pp. 83-99