Break it better

Blast fragmentation should be optimised for material haulage, comminution and mineral processing. John Chadwick examines some technologies and the benefits accruing.

Jack Eloranta of Eloranta & Associates stresses the importance of timing a blast properly. "It may take days or weeks to drill out a pattern and loading might take hours or days. But, the time span that really matters is the interval from the detonation of one hole to the time the adjacent hole fires. Modern detonators have revolutionised blast timing. Not only has precision improved by an order of magnitude, but complete flexibility is now a reality. If you want 1 ms or five seconds of delay – just dial it in.

"So, with timing solved, it is time to focus on other more pressing blast design problems – right? Not quite so fast. Just because the technology is available, it doesn’t mean the understanding has caught up.

"Recent laboratory work by Katsibanis and computer modelling by Preece have confirmed that the window of opportunity is narrow. There is, as well, a great deal of speculation regarding the interaction of shock waves. However, there is little supporting evidence as to the benefits of colliding shock waves.

"The window of opportunity is short. It is critical that from the instant of initiation of one powder column there is a narrow range of time that the adjacent hole must fire. When the time is too short, the late work of the first hole is stopped and the full potential of creating a fracture network is not achieved. Conversely, when the delay time is excessive, the second hole is shooting into a fractured rock mass with openings between fragments. In the extreme case, shifting occurs which may result in offsets and cutoffs of the powder column. Such disruptions may be much more prevalent than previously thought. Research by Rogers and Lee indicates that stemming decks may need to be at least 10 diameters in length (as opposed to the old rule of thumb of six diameters). This means that that a blaster who..."
non-disruptive fragmentation analysis technology analyses material as it dumps into the primary crusher is experiencing offsets may not necessarily be finding un-shot powder in the muckpile. Powder can be consumed via deflagration rather than detonation. Such low order combustion has been shown to contribute to nitrous oxides and orange smoke. Further evidence of offsets lies in VODR (velocity of detonation recorder) data. The success rate for capturing detonation velocity in the field is low. The initial hole in a pattern is often the only clean record.

To conclude, your timing will be dictated by several constraints. High on the list will be avoiding misfires due to cutoffs and avoiding high ground vibration at neighbouring properties. Other high priority constraints may include: minimising movement for dilution control and matching muckpile profile and digability to loading equipment. Once these high priority concerns are met, further timing tests can be done to optimise downstream processes such as crushing and grinding where the greatest savings lie. In the final analysis, one might say that modern detonators result in an increased effective powder factor thanks to full order detonation of more of the powder column."

WipWare says that with the introduction of WipFrag in 1986, it “became the industry leader in optical granulometry of fragmented material. Since that time, the company has built a global reputation for excellence in software innovation and design.” With WipFrag, Momentum, Reflex and Solo; WipWare continues to provide customers with innovative solutions to optimisation and automation needs.

With innovative fragmentation analysis technologies, companies are now able to establish blast consistencies, and can track relative changes in ore size, based solely on the data provided from these systems. The results include reduced maintenance costs, improved blasting procedures, and increased throughput.

Gyratory crushers are typically adjusted every five to seven days depending on the operation. Now, companies are focusing on real-time fragmentation data, and using key performance indicators to determine how much downtime and maintenance is necessary when gapping.

At one particular operation, rules were set to adjust the gap settings automatically using hydraulic toggle technology along with fragmentation data from an online system. The results can show a number of different things, but most importantly it tells the operator either:

a) The crusher needs to be gapped on a more regular basis based on the increased fragmentation size
b) The crusher is being gapped too often when it is not required, allowing for less downtime.

Further into the comminution circuit, being able to adjust the SAG mill feed based on real-time data has allowed operators to optimise the size of material going into the SAG. This, in return, has increased the throughput at many operations worldwide, and has reduced liner wear significantly.

Mark Wagner of WipWare notes that “when monitoring fragmentation at three crucial parts of the mining process, mining companies have developed a better sense of what is passing through their process, and have adjusted blasting and crushing procedures accordingly.”

I-Blast is blasting simulation engineering software to help optimise results without delaying the blasting process. The DNA-Blast model provides a “holistic” and realistic model of rock breakage, and consequently of The fragmentation result is displayed instantly and can be sent via email to operators throughout the operation fragmentation distribution size, taking into account all key parameters involved such as geology, explosive features, drilling pattern and timing sequence.

DNA-Frag is a paradigm shift in fragmentation simulation versus traditional purely statistically-based simulation tools. Furthermore, the DNA-Blast model enables a new proven approach and sets a new standard in blast design, thanks to its fragmentation module and its new simultaneous simulation capability for vibration, air blast, fly-rocks and muck-pile shape.

Multiple blast scenarios can be run before selecting what should be the most effective combination that best suits operational objectives. DNA-Blast allows a seamless quantification and size estimation of the fragmentation and delivers a size distribution of rock either in a muckpile or on a conveyor belt, for a considered hole or for the whole blast, thanks to a unique image compilation feature (see the bottom part of the screenshot).

The DNA_Frag module, takes into account all the field data at hand to accurately predict blast results – real burden and spacing face geometry, rock mechanics characteristics, explosive hole loading, angle and co-ordinates, explosive characteristics and behaviour.

The DNA-Frag module shows an average 90% accuracy in the prediction over recent years. Complete muckpile screening campaigns even show these figures to be somewhat underestimated, says the French inventor of the technology, Dr Thierry Bernard.

The DNA-Blast Energy Optimisation Module was integrated into I-Blast in early 2011 and
adds a decision aid tool that simulates all the possible initiation sequences in your configuration, pinpointing the sequences that best optimise the energy inside the blast.

Aiming at providing an Optimized Explosive Energy Release time design, Bernard applies the principle of mass conservation to the explosive energy: less energy dissipated in vibrations means more energy for fragmentation. “Ask somebody who is using electronic detonators for vibration control. He will say that the muck pile is uniform and the fragmentation has improved. This is exactly the principle we apply in DNA-Blast Technology”, says Bernard.

The use of signature hole principles, and subsequent vibration analysis allows the mitigation of the energy waste that is responsible for adverse blast effects such as vibration, air blast level and fly rock.

The DNA-Blast Energy Optimisation Module gives you the opportunity to process either a Far Field or a Near Field Signature hole. Using a Far field analysis, an average number of holes per row and an average number of rows are considered to give you the best trend for Inter Row Delay and Inter Hole Delay.

Relying on a Near field Signature, the module takes into account blasting pattern configuration, the x,y,z hole location, the number of holes, hole loading and configuration. It provides the optimum timing sequence among a screened range of Inter Hole delay and Inter Row Delay.

The yellow areas show where the amount of wasted energy is minimized outside the blast. Selecting the corresponding delays will optimize your blast which results in less vibrations and a better fragmentation.

A 35% drop in excavation and comminution costs through the application of optimised timing has been reported by one North American open-pit mining.

“I have successfully used I-Blast at over 35 sites and over 500 blasts and the software performed as expected with vibration, air overpressure, and fragmentation results occurring as predicted”, says John Babcock, Executive Technical Director at South Technical Services, based on his experience in providing engineering and advanced technical services to the quarries of the East Coast of the USA.

The three most important factors in blasting are drilling, drilling and drilling, according to BME. Expecting explosives to provide totally satisfactory results when preparation and drilling on site has been poor is not only totally unrealistic, but can also be expensive. The result of poorly drilled blast sites is a substandard outcome, poor fragmentation and ultimately lost production, says Tony Rorke, Director of Blasting Technology at BME, one of South Africa’s leading suppliers of explosives.

“The belief that explosives will compensate for poor drilling at a blast site is more common than most people would think,” says Rorke who says that he is often requested to deal with requests to use technology and explosives to solve what miners already know to be poorly prepared blast sites.

Amongst the most common requests for assistance are:
- To do timing designs that will “ensure good fragmentation and low vibration” when drilling has already been completed
- To request the application of electronic detonators to improve blast results at sites where poor drilling quality is endemic. The significant benefits when using accurate electronic detonators are completely overshadowed by poor drilling quality. Most commonly, however, is the claim that drilling is not the problem. “I am often told that high bottoms are being experienced on blasts and that it is the explosives, the blast design, the initiation system or both the initiation and blast design that is at fault. Unfortunately, this is rarely true. Poor drilling quality or inappropriate drilling patterns are usually found to be the heart of the problem,” says Rorke.

The causes of poor blasts are many and can range from poorly trained drilling crews and drill foremen, through to teams working with an insufficient number of drill rigs and having to work under pressure to try and maintain production rates.

Other factors that have a negative impact on drilling results can be drill rig fleets that are inappropriate for the mining geometry or rock in an area and difficult environments where drilling quality and measurement is difficult. This scenario is most common where handheld drilling is required in narrow stopes or development ends.

“I am often asked when on site what the sources of errors in drilling are,” says Rorke. Summarised they are distances between holes. Holes drilled too close together result in over-fine rock fragmentation. Explosives in nearby unfired holes may become damaged and not detonate properly or it may detonate sympathetically impacting on the quality of fragmentation.

“Most common are holes being drilled too far apart resulting in coarser fragmentation and high floors. This is particularly the case in harder rock.”

Other problems are collaring caused by the drill operator drilling in the wrong place due to a number of reasons. Angle errors result in off line deflections, most common in smaller diameter holes, or the boom of the drill rig being set at an angle different to the desired hole.

Hole depth is another problem: short holes result in high floors or capping, or holes that are too deep cause damage to rock below and result in drilling problems in the following bench.

Hole positioning where holes are often drilled into badly damaged rock from previous sub-drill damage. “Very often, sub-drill damage is so high that a re-drill is impossible and the area ends up without a hole. Missing holes have a very deleterious effect on floors and fragmentation in a blast,” says Rorke.

Hole diameters influence the dispersal of energy and result in either “explosive energy starvation” or “excessive energy” that lead to rock damage and a risk of under-filling. “Small variations in diameter have a very significant...
impact on energy in a blast, especially in larger diameter holes. Again there are many reasons for these errors occurring,” he says.

“Drilling needs to be given high priority in the production cycle and should not be treated as a basic operation where operator training is minimal and inexperienced foremen are used. Explosives and blast timing cannot correct poor drilling. Poor drilling will result in bad blast results, he concludes.

Of course stemming blastholes can help. Varistem says its system “reduces processing costs, with the Varistem achieving up to a 25% increase in fragmentation. Studies also show the Varistem can reduce blast patterns by 10% or greater and achieve the same result. He concludes.

The two types of angle errors that can occur. Well-trained drill operators can minimise this type of error although hole deflection errors are more difficult to eliminate.

The primary advantage of the DFM is to increase the realisation of blast pattern design,” Owen continued. “This reduction in variation from design to actual allows for more accurate blast modelling. Manually surveyed patterns characteristically have large enough error to potentially invalidate correlations of blast parameters and blast results. As a primary element of successful blasting, energy distribution is achievable when assisted by the DFM.”

The SFA captures images of active dig faces for all large production shovels. Owen explains that “the images are manually cleaned of unusable images and automatically processed. This data is stored on a database where each image is collated to a GPS coordinate of the location where the image was taken. This combination of information has increased the ability to systematically judge fragmentation results.

“The SFA reporting allows for very detailed feedback on blasting performance while the DFM allows for blastholes to be placed within a half-diameter error of design. The other parameters necessary for blast design and reconciliation are also captured to create a full process map. This data includes bulk explosives information, detonation details and accessory utilisation. These items are combined with the

Hole positioning relative to damage contour line caused by sub-drill from previous hole positions in blast above
Both blast performance from a processing geotechnical parameters and their impacts on more important. Integrated data allows the designed, geotechnical parameters become expanded, steepened and new mines are to vary as the mine progresses. As mines are evolving needs is critical. This integrated process to adapt in a timely manner to both upstream and downstream processes.

Aspects, blasting performance will better suit environment. By fully integrating these blasting test results into the production with less time allows for greater integration of quick data analysis with more detailed results. This ability to see impact on multiple variables is directly influenced by many factors, both in design and terrain, and can influence much of the ultimate mine design and cost realization. The technology exists to reduce analysis time and build sufficient models to accurately predict rock fragmentation. The integration of data sources and the application of this data into the process is the key to success. The future of blasting is here and will only continue to develop as new technologies are developed."

K. M. Kim, of ASARCO (Grupo Mexico) and J. Kemeny, The University of Arizona, reported on Site specific blasting model for mine-to-mill optimisation. This blasting model has been developed for the Asarco Mission mine. "The main inputs to the model are the in-situ block size (F80), the post-blast fragmentation (P80) and the intact tensile strength (T0). The output from the model is the specific blast energy (ESE). Modern techniques are being used to obtain the input parameters for the site-specific blast fragmentation model. In particular, image processing software is used to the requirements may change as equipment is changed. Blasting can accommodate crusher throughout limitations, contributing to the mass reduction from the initial blast. This can easily be evaluated from a cost standpoint allowing for the money to make the largest impact: more crusher capacity or more money spent in the initial blast. In leaching operations the reduction of ROM material may realize immediate and significant profit increases. From total recovery to recovery times, the size of material in a ROM leach pad is very influential. In milling processes the ability to impart micro-fractures and small initial input size can greatly reduce the energy and time requirements to realize particle size. Waste material may not require small size fractions, but fragments that are too large may cause unnecessary damage to equipment or loading hardships for personnel. By optimising these and many more downstream processes it may be possible to reduce or streamline the types and amount of blasting products purchased.

Improved maintenance may reduce work hours required to keep equipment running and increase production."

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obtain both the in-situ block size and the post-blast fragmentation, and the Schmidt hammer is used to obtain the tensile strength at numerous locations throughout the rock mass.

An initial model was developed using five test shots in one area of the mine that contains Argillite and is relatively homogeneous. This also included calibrating Schmidt hammer readings against actual Brazilian tensile measurements. The model for Argillite will be updated as more tests are conducted, and the model will be extended to the other four primary rock types at the Mission mine.

“In modern blast fragmentation modelling, the parameters must be easily attained at numerous locations throughout the rock mass.”

“The purpose of the site-specific blasting model is to optimise blasting for total cost or total energy, including downstream comminution and mineral extraction. In general, increased explosive energy will result in finer fragmentation and increased rock damage (microcracking). Thus, even though the drilling and blasting costs may increase, the total mine-through-mill costs will decrease. There is a limit, however, and there is a point at which further increases in drilling and blasting costs will increase rather than decrease the total cost. The site-specific blasting model developed in this paper can be used to find that optimum point.

“A preliminary study was conducted to look at total cost savings vs. blast energy for a hard and soft rock, and indicated optimum blast energies of 225 and 175 Kcal/t for hard rock and soft rock, respectively.”

Better fragmentation through team work at Dos Pobres mine, Safford, AZ, by D. Brandt et al, considered this a copper oxide heap-leach mine where, as mine depth increased, “the proper fragmentation size became harder to achieve due to less weathering and different rock types. Because copper recovery increases as crusher product size decreases, achieving the appropriate product size at the crusher is the operating priority.

“The Engineering Department started a project to improve fragmentation through blasting and thus increase throughput in the crushing system. It soon became clear that input from other departments was going to be required to make this a safe and economical project. Therefore the Crush and Convey and Ore Control departments worked together to evaluate all available data on blast patterns and explosive loads and tracked performance and results. Using image analysis, Drill Energy Index and databases, we have been able to improve fragmentation size and verify the results while controlling costs.”

They concluded that consistent blasting practices have resulted in better control and consistency in fragmentation. "This is evident from the crusher performance, crusher screen data and from the camera image analysis data. The costs associated with the improvements have not increased overall costs. Costs for increased drilling have been offset by using less explosive product or products of lesser strength. Costs have also been reduced by the increase in hauling efficiency, crusher throughput and less crusher wear.”

Effective blast?
When evaluating the effectiveness of a blast, it is important to obtain the rock fragmentation results as close to the blast as possible to prevent inaccuracies due to handling of the material. Motion Metrics International’s

FragMetrics™ solution provides rock fragmentation analysis from the shovel bucket, which is typically where the first stage of material handling occurs.

The images used for fragmentation analysis are automatically captured using a rugged camera installed on the top of the boom of an electric rope shovel, or on the stick of hydraulic face shovels. Specially designed brackets position the camera to have a clear view of the bucket during operation and help to isolate against shock and vibration.

The embedded computer, installed in the operator’s cab, tracks the bucket as the shovel is in operation, and automatically logs images of the contents. Advanced real-time image processing algorithms are used to filter the images based on image quality and bucket contents to select only the images suitable for fragmentation analysis. A collection of images are sampled through the face as the shovel excavates to provide a representative fragmentation measurement. The logged images can then be accessed over the mesh network or directly via the on-board industrial-grade CompactFlash card.

Motion Metrics offers two options to perform the fragmentation analysis; a stand-alone tablet computer, FM-Tablet, or a service contract-based agreement, FM-Service. The FM-Tablet provides the tools to process and review the analysed fragmentation results, and generate automated reports, in a compact tablet computer. This option is favoured for performing routine assessment and maintenance of blasting performance. The FM-Service employs Motion Metrics specialists to perform the processing and reviewing of fragmentation results to provide fragmentation reports. This option has been popular for mines that would like to perform a third-party assessment of a blasting consultant, or carry out a study on the effects of blast fragmentation on a particular mine process.

Blast fragmentation has far-reaching effects on the performance of equipment and processes throughout the mine. Fragmentation affects the looseness or daggability of the bench face, which influences excavation efficiency, while the throughput and energy costs of primary crushers are directly related to the input feed rock sizes.

To provide a more comprehensive collection of information, the fragmentation data can be correlated with data from other Motion Metrics shovel solutions. For example, correlating the fragmentation data with the
shovel tooth-wear data from WearMetrics™ and shovel productivity information from LoadMetrics™, allows the mine to monitor the relation between blasting and shovel operation efficiencies to optimise future blast practices.

**Lowering dilution**

A Queensland innovation in electronic blast detection received Australian recognition for excellence in the application of Information and Communication Technology (ICT) at the iAwards. Judges sited the BMM system’s use of innovative technology, ease of application and its potential to significantly reduce ore loss and dilution at any open-pit mine that uses selective excavation.

With mines routinely recording a 5 to 20% loss of valuable mineral in every blast, BMMs already save mining companies tens of millions of dollars per mine every year.

The inventors of the BMMs formed a company, Blast Movement Technologies (BMT), to commercialise the combined hardware and software grade control solution in 2005 after conducting initial research at the University of Queensland. Since then, the prototype has been transformed into a robust commercial product now used in mines across Australia and in more than 10 countries around the world.

The BMM system works by placing hardened transponders into drill holes in an orebody prior to blasting. After the blast a portable detector is used to locate the new position of the markers, thereby determining the movement vector of the blasted ore. Ore has often moved more than 10 m.

Once downloaded to BMT’s proprietary software the information is quickly and easily transformed into accurate, 3D movement vectors, redefining ore boundaries, and enabling the most precise identification of ore and waste available to the industry, BMT claims.

BMT Director and Principal Consultant Darren Thornton said the award was a highly valued recognition of the quality of this advanced system. “The team at Blast Movement Technologies has worked tirelessly to lead the mining industry into an age where the precise measurement of muck pile movement can now have a significant impact on improving mine reconciliation.

“When we begin working with a mine we perform a comprehensive evaluation of existing blasting practices while training staff on just how easy it is to use the Blast Movement Monitors. Most mining engineers and senior managers accept ore loss and dilution as a cost of doing business, however they are always surprised by just how much money they are losing by unintentionally dumping high grade ore as waste, and shipping useless waste to the plant for expensive processing,” Thornton said.

“All of the mines that we work with have recorded significantly decreased loss and dilution, which translates directly to increased profits. Improved reconciliation of planned versus actual ore grades enables more control of the mining process.

“Once the site team is actively using the system as part of its blasting procedures we provide ongoing support and maintenance as required,” Thornton said.

The system is currently being used by leading Australian and international mining companies including Barrick, BHP Billiton, Mt Gibson Iron, Newcrest, Newmont, AngloGold Ashanti, Goldcorp and Rio Tinto. **IM**