Going to pieces

John Chadwick considers better drilling and blasting, stemming, blast monitoring and secondary breaking

Drill and blast efficiency can significantly impact the cost and productivity of downstream activities, including loading and hauling, equipment maintenance, crushing, and processing. As equipment downtime, operator error, and material output impact a mine's bottom line, so too does optimally fragmenting the ground. Improper fragmentation produces many negative results, including broken excavator teeth as a result of excessive wear, difficult digging as a result of excavating rocks that are too large, and mills and crushers being taken offline due to damage caused by these same large rocks. Similarly, energy consumption rises.

Orica poses the question, "what if drill and blast wasn't thought of as a cost centre or a necessary spend to enable excavation and easier comminution?"

Mines have run projects to test whether their drill and blast design parameters are the most appropriate for the site and whether they result in the lowest overall cost of production. Many of these test projects struggle to produce any compelling evidence to justify either an increase, or decrease in dollars (or energy) spent on drill and blast.

As Orica notes, "it isn't a simple problem. Mining is a complex mix of many interrelated activities and blasting is heavily influenced by the variability of the rock mass it's applied to. Additionally, downstream activities such as load and haul, and crushing/milling are also influenced by variables, other than just blast results."

In recent years the industry has begun adopting various technologies to improve the understanding of blasting outcomes. One such example is taking photo images of blast muckpiles and using algorithms to calculate the fragmentation distribution for each photo. It is, however, a manual process and subject to several sources of error and bias. The sample size of photos taken and which part of the muckpile is being photographed will determine the analysis (eg immediately after firing only captures the upper section of the blast bench).

"There are automated systems in the market, but limitations remain," Orica says. "One type of system is mounted above a conveyor and measures particle size after crushing. Whilst the conveyor system does measure the rock fragmentation, the material is often blended before arriving there. This means there is no automated way to efficiently link the fragmentation distribution of a photo to a specific blast in the mine."

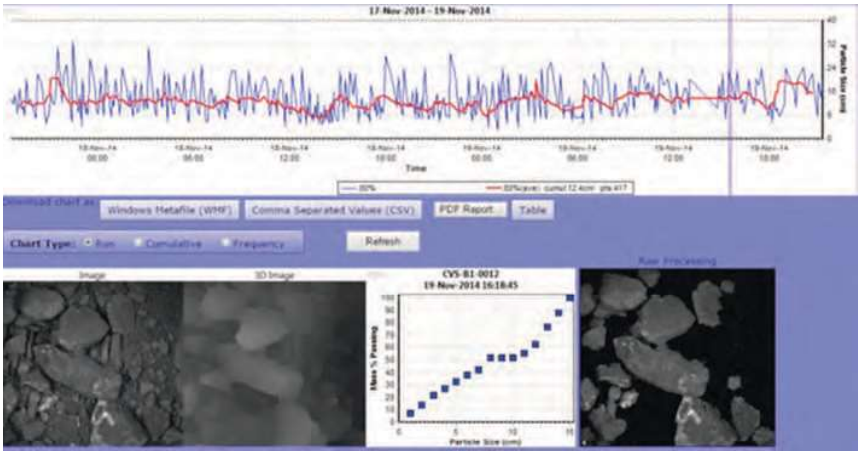
Orica is working in partnership with customers to deliver a range of fragmentation measurement and optimisation solutions, using marketing leading technologies, systems support and application expertise. Successful pilots with customers at various mines around the world have provided rich learnings, driving the development of Orica's own FRAGTrack™ measurement systems. As an example, issues with the quality of automated image analysis from face shovel mounted systems, with sunlight-induced shadowing effects, have been addressed using binocular systems and unique algorithms. FRAGTrack's combined 2D and 3D algorithm analysis handles shadows and variable lighting.

First launched in 1998, RIOFLEX is MAXAM's flagship explosive, developed with the company's own in-house R&D – key to MAXAM's technological independence. Thanks to its versatility and high energy, RIOFLEX has, the company says, "consistently delivered exceptional results for clients worldwide." It is effective in both cartridge and bulk formats, can be used in extreme dry or wet conditions and has the proven ability to be deployed across an extreme temperature range, as it is currently used in climates with temperatures ranging from 40°C in sub-Saharan Africa to -40°C in Siberia, Central Asia and Canada

Customers have validated the need for a more comprehensive understanding of fragmentation measurement. By understanding fragmentation from blasts and linking this data to downstream productivity KPIs, such as digging productivity and plant throughput/energy intensity, engineers have been able to optimise blasting to create greater value. Digging productivity has been improved by reducing top size. Plant throughput has been improved by notifying the plant of expected fragmentation, well before the ore reaches the plant. Drill and blast engineers have been able to improve successive blast designs, by seeing fragmentation results from previous blasts, before designing new blasts.

It is Orica's opinion that "the industry is yet to see a seamless, scalable solution that provides miners with an automated way of measuring and comparing fragmentation performance of blasts, generating valuable insights to enable the continual improvement of blasting performance. Consequently, miners are forgiven for continuing to treat drill and blast as a cost centre, with limited potential for value adding."

Orica has a vision to transform the way the industry views the drill and blast process. This includes a clear roadmap to deliver global solutions, working in collaboration with miners and industry partners.



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Orica Senior Manager, Global Marketing Digital, Angelo Labriola, said: "Miners see the significant opportunity to unlock value by optimising drill and blast, but they are unsure how to systematically achieve this. On a daily basis, drill and blast engineers work actively to design blasts and release them into production. They strive to make blast improvements, but without an automated system that integrates measured results with blasts, they are essentially operating blindfolded with their designs.

"By systematically optimising blast results, miners can improve digging productivity, reduce ore dilution and energy intensity in comminution circuits, ultimately increasing overall mining value."

Consider an operation where the processing department knows the optimum feed, in terms of the fragmentation distribution to maximise throughput, minimise downtime/maintenance and/or minimise energy consumption. This is communicated to the mining department and blasts are customised to deliver to that specification, accurately and consistently. This would apply across different areas of the mine, irrespective of geological variation.

Orica is actively working to make this a reality. This includes delivering the enabling technologies and system intelligence, backed up by specialist support. At the dig face, fragmentation measurement and automated analysis data will stream from these systems and be linked to the blast data platform. Fragmentation data is then readily associated with the blast design, allowing insight into how fragmentation is affected by energy and timing, applied in any part of the blast.

Another key variable driving blast results are rock properties, which are broadly understood from mine block models today. However, a far more detailed understanding is required to consistently blast to a specification. The next frontier sees data from smart drills and augmented sensors interpreted using artificial intelligence (AI) to accurately define rock properties for the proximity of every blast hole.

The seamless integration of rock mass data, drill and blast data and fragmentation data into a platform with intelligent blast design capability, enables blasting to specification. Miners will have a comprehensive picture of the relationship between blast energy, the rock mass and fragmentation, together with the technology to design for a target fragmentation specification every time.

This advanced approach will mean blast designs need to be tailored for a specific blast outcome, to ensure accurate implementation in the field. Orica's BlastIQ™ technologies enable drilling accuracy to be measured prior to loading. Necessary adjustments can be made to a loading plan on a hole-by-hole basis, without the drill and blast engineer manually reprocessing the design. Orica's Mobile Manufacturing Units (MMU™s) integrated with LOADPlus™, a BlastIQ enabled smart control system technology, will very soon wirelessly receive blast designs, while on bench. They will load the correct explosive type and quantity to deliver the design outcome. As-loaded hole-by-hole data will be consolidated in BlastIQ, then integrated with fragmentation measurement and rock properties.

"Data enabled blast optimisation will finally allow an industry scalable alternative to blasting for drill and blast cost centre management. Connected and digital-enabled drill and blast systems, real time measurement and analysis of both rock properties and blast fragmentation, together with AI-enabled quality blast design, will achieve blasting for mine cost optimisation. This will be a pivotal moment for the global mining industry," Angelo concluded.

Differential energy

Using an optimisation study that covered a 20-month period in 2014 and 2015, a customer found a high percentage of fines in its blasted stone. The customer called in Dyno Nobel's DynoConsult team to help study the reasons and find a cost-effective solution.

Before the study began, an audit was conducted to validate sound loading practices and the precision of drilling. Also, a standard blast was conducted to determine the baseline data on particle size and speed of the primary crusher.

The approach was to make one change at a time in the blasting parameters to measure the impacts on variation in particle size and crushing.

The project's aim was to improve and reduce fine particles smaller than 31.5 mm. The 0.08 mm passing size was not to exceed 11% of the range from 0.08 to 31.5 mm. Otherwise, production was rejected. A secondary goal was to improve overall fragmentation of blasting, improving the optimal range of 31.5 mm to 1 m.

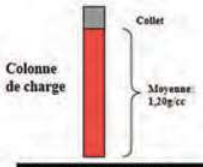
The sampling methodology consisted of taking a portion of stones after the primary crusher at every 7,000 t crushed from the blast under the study. After that, the sample was sent for analysis to an outside laboratory.

The technology involved in the study was differential energy, which allows alteration of the segment gasification rate (maximum four segments) in a single hole and in a single loading phase. For this study, more than 15 blasts were required to determine the parameters best suited to meeting the project's goals.

The benchmark blasting was done based on the quarry's conventional parameters (blast no. 2014-08). In examining this blast, it was possible to determine the distribution curve of the fines. It was found that the 0.08 mm passing size came to 10.8%, close to the 11% limit.

In blast 2014-12, the drilling parameter was retained, and the loading level was much the same: 0.90 kg/m³ for blast 2014-08 and 0.92 kg/m³ for blast 2014-12. The use of two-segment differential energy allowed the average load density of 1.2 g/cc to be maintained in the hole (see Figure 1: bottom segment 1.26 g/cc and upper segment 1.15 g/cc).

After blasting, an improvement in the 0.08 mm passing level was observed, from 10.8% to



Paramètre de sautage	
Profondeur (m)	15.54
Diamètre de forage (mm)	121
Sous-forage (m)	1.21
Collet (m)	1.83
Espacement (m)	3.35
Fardeau (m)	3.96
Type de patron	rectangulaire
Densité du produit (g/cc)	1.20
Taux de chargement (kg/m³)	0.90
Zone	P2-E4

Pourcentage passant										
31.5 mm	20 mm	14 mm	10 mm	5 mm	2.5 mm	1.25 mm	0.63 mm	0.315 mm	0.16 mm	0.08 mm
100	98	83	69.5	49.5	38	29	22.5	18	14	10.8

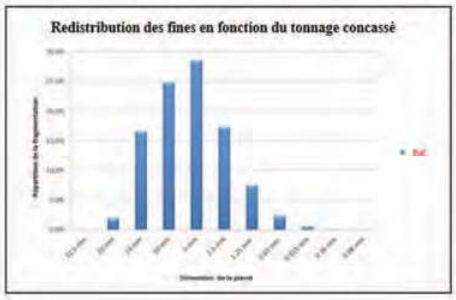


Figure 1

6.5% (see Figure 2).

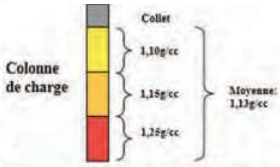
After several trials, blast 2015-08 enabled the best overall result to be achieved. The drilling diameter was lower, at 114 to 121 mm, the drilling pattern was reduced by 7.8%, from 3.35 m x 3.65 m to 3.35 m x 3.96 m, and the loading level was higher, at 0.97 kg/m³ instead of 0.90 kg/ m³.

The average density in the hole was altered, from 1.20 to 1.13 g/cc. This lower average density in the hole was achieved by using three-segment differential energy (bottom segment 1.26 g/cc, middle segment 1.15 g/cc and upper segment 1.10 g/cc). A decrease in 0.08 mm passing fines from 10.8% to 5.7% was observed in comparison to the benchmark blast and from 6.5% to 5.7% in comparison to blast 2014-12.

Differential energy played a major role in improved fragmentation. In the second figure on particle size analysis of fines, the effects can be seen. Among other things, in curves 2014-12 and 2015-08, an improvement in 0.08 mm passing fines can be analysed, from 10.8% to 5.7% passing stones, representing a 52.7% improvement.

In overall blasting, several other positive improvements were obtained in fragmentation:

1. A lower proportion between 0 and 31.5 mm, from 21.02% to 15.56%, a 26% improvement
2. The optimal fragmentation range, between



Paramètre de sautage	
Profondeur (m)	13.5
Diamètre de forage (mm)	114
Sous-forage (m)	1.21
Collet (m)	1.5
Espacement (m)	3.35
Fardeau (m)	3.65
Type de patron	Rectan
Densité du produit (g/cc)	1.13
Taux de chargement (kg/m³)	0.97
Zone	P1-XX

Pourcentage passant										
31.5 mm	20 mm	14 mm	10 mm	5 mm	2.5 mm	1.25 mm	0.63 mm	0.315 mm	0.16 mm	0.08 mm
100	98	83	69.5	49.5	38	29	22.5	18	14	10.8
100	98	81	66	40	26	17	12	9	7	5.7

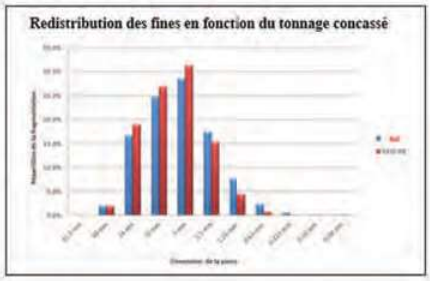


Figure 2

31.5 mm and 1 m, is maintained, marking an increase from 76.97% to 81.31%, a 5.33% improvement.

To conclude, it was shown that the use of differential energy helps improve fragmentation to obtain a desired particle size, due to energy being distributed in the right places.

Explosives and software

MAXAM's Rioflex technology was developed for use in hard rock surface operations in Australia. However, its excellent performance didn't go unnoticed by customers around the world, and its use spread. Since its use started more than 30 years ago, Rioflex has been proven in more than 140 sites in 25 countries. MAXAM says "it has become a reference for improving the productivity of mines."

Rioflex is a high energy, robust and flexible density explosive, representing the latest development in bulk explosives technology. It is charged into blastholes by innovative delivery systems over a wide range of energies and densities. The density of the product can be adjusted from 0.6 to 1.35 g/cm^3. Rioflex can also be customised to deliver shock and heave energies to fragment and move the rock mass as needed, creating the muck pile required for efficient excavation.

This increased flexibility gives a better energy distribution in the blasthole, reducing sub-drilling requirements and resulting in improved floor levels. This customisation permits the use of expanded drill patterns and lowering of total costs.

The technology allows Rioflex to crosslink in the hole, reducing product migration through cracks in the rock and reducing stemming dilution. This high-level control mitigates uncontrolled blasts, reduces flyrock incidents and reduces post-blast fumes.

It can be manufactured with different types of ammonium nitrate, facilitating the use of nitrate from different sources, and increasing the security of supply to anywhere in the world. Rioflex is robust, and can be stored for extended periods of time and transported long distances, while maintaining its quality.

It can also improve safety. For example, the use of mechanically gassed Rioflex permits immediate stemming and precise control of the stemming height. Increased stemming control and crosslinking in turn helps reduce fly-rock events, enhancing safety. It can also be used to blast in hot or reactive grounds.

Rioblast is a complete blast design and simulation software suite to manage one blast, or an entire drill and blast campaign. Developed by MAXAM, it helps mine engineers and blast designers to optimise the use of explosives and initiation systems, and to accurately predict

"The development of the X-COPTER is the result of synergistic gains between in-depth knowledge of mining activity and the application of the latest technological advancements in the field of robotics, aeronautics and electronics", explains Diego Fernandez, General Manager of EXPACE, a MAXAM Group systems company that focuses its activity in the areas of electronics and ICTs, and collaborates with the group's different business units for the development of drones and innovative technologies applied to the defence, security, aerospace and industrial sectors

desired fragmentation, ground vibrations, and safety circles.

It can also be used to analyse the results, and to generate blasting reports with ground vibration and fragmentation data.

A simple, user friendly, interface lets the Rioblast user import actual topography data of the terrain or bench, and work with the data in an intuitive 3D environment. It seamlessly integrates data from laser profilers, topographic surveys, satellite and drones photos, with the characteristics of the explosive and rock properties.

It consists of eight integrated modules (terrain, blast geometry, timing sequence and delays, ground vibration, fragmentation, flyrock, blast plans and reports, and project management) designed to add value and help to solve the daily challenges of the drilling and blasting operations.

Advanced reporting features allow the Rioblast user to create detailed blast plans, blast reports, map overlays for ground vibrations and safety circles, and other useful information.

MAXAM's X-COPTER is a quadcopter providing aerial reconnaissance of open-pit mines. Equipped with cameras and gas sensors, it offers the ability to check the safety of the land before and after blasting, as well as performing a structural analysis to measure aspects such as fragmentation levels and volume of material generated.

To increase the efficiency, quality and safety of mining operations, the drone has a series of key functions such as: gas sensors (CO and NOx), real-time HD video and photography, greater flight autonomy and the ability to operate in wind and light rain conditions.

Rioblast also enables a segregated classification of the rock mass into as many zones as necessary, based on rock properties of the different zones, be it for designing a single blast, or an extended blast campaign. This improves the accuracy of the predicted fragmentation curve. Comparing the predicted fragmentation to the one obtained and applying corrections to subsequent blast designs, permits the software to achieve "unparalleled accuracy in predicting fragmentation," MAXAM says. The user can experiment with different blast designs, timing sequences, delay timings and rock movement on the screen, and then choose the one best suited to the outcome desired.

Rioblast can be customised to meet the specific needs of a project or a mine. For example, a dilution model can be added to design blasts to control dilution. Another module permits the design of underground blasts. It is also a powerful management tool. Its library stores information about the terrain, blasts design history, costs, explosives, blast reports, etc, which facilitate a continuous improvement process for any operation.

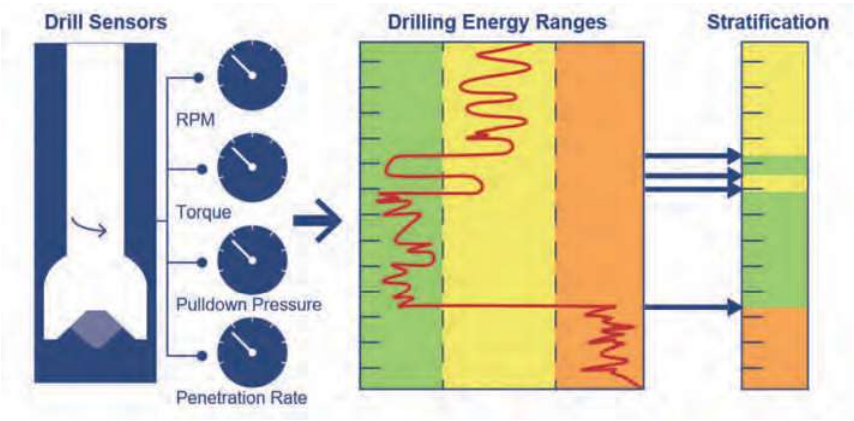
Modular Mining Systems says its ProVision high-precision machine guidance system and optional Drill Hole Stratification module can significantly improve fragmentation results, as the solution provides precise navigational accuracy plus data and energy calculations that can help refine drilling and blasting processes. These refinements can increase equipment life and cost savings while improving productivity and safety.

ProVision guidance provides open pits with positional accuracy up to 10 mm. This precise guidance helps increase total tonnes moved and improves material movement accuracy, while decreasing costs associated with working outside of the mine plan.

The ProVision Drill system provides continuous onboard drill hole position navigation, depth, and angle to dramatically improve blast-hole drill rig efficiency, utilisation, and compliance with established goals. Additionally, the high-precision GPS navigation continuously guides operators through poor visibility and while working at night, further improving drill utilisation.

Successful fragmentation depends upon several factors, including explosive type, detonation timing, drill hole spacing, drilling accuracy, hole depth, and rock hardness. Utilising a stratification or 'rock recognition' system can help manage this equation, as these systems help to improve drill hole design based on bench geology patterns. The ProVision system's Drill Hole Stratification module helps to optimise blast-loading design.

The module allows the assignment of typical ranges of drilling energy to a set of materials or hardness, based on configurations determined by geophysically-measured drill holes at certain regions or elevations in the pit. The ProVision Drill system continuously monitors such real-



Modular Mining Systems' ProVision Stratification module improves blasting performance, blast-loading design, and dig-ability

time drill data as speed, pulldown pressure, torque, and penetration rate, then immediately sends this information to an office server, where it is stored in shift databases. The stratification module then calculates specific drilling energy for each hole after drill completion, mapping the energy layers of the material from each hole into their respective material or hardness categories. Users can view stratification results via graphical reports or by exporting CSV files to mine planning or blast management software packages.

When fragmentation for one bench is known, the ProVision system analyses the stratification results to determine a new blast pattern for subsequent benches. This allows mine operators to tailor blast patterns to specific bench elevation, rock hardness, and explosive type, resulting in more consistent rock sizes.

Stratification improves blasting performance, blast-loading design, and diggability, all of which impact successful fragmentation. Data gathered by geological patterns and blast results provide valuable insight for neighbouring blast designs; the ProVision system leverages this data by sending up-to-date blast patterns to equipment operators automatically. This facilitates the continual fine tuning of geological models, helping to improve explosives management and decrease consumables costs. For example, as the ProVision system continuously polls bit depths, it measures such parameters as RPM, torque, penetration rate, and pull-down pressure, which provide valuable clues about the location of voids resulting from underground water, old underground drifts or other sources. "These void identifiers can result in significant monetary savings, as they allow the operator to make better-informed decisions about which explosives to use," says Charles Orr, Modular's Product Manager, Machine Guidance. "When the stratification module identifies underground water, for example, blast planners will know that they need to use a waterproof explosive to allow for proper detonation."

There is also a consideration of improved ore control. By significantly improving material fragmentation, stratification can also reduce ore loss or dilution. As the stratification module identifies the varying layers of material within a hole, it informs miners about the concentration and location of the desired ore, making extraction easier. Additionally, since the ProVision system uses the stratification details from one bench to refine and update the drill pattern for subsequent benches, miners gain additional ore control with each drill and blast cycle. These continual refinements also help to waste less ore from poorly-broken pattern 'edges.'

Stratification can help improve operator safety in many ways. It can significantly reduce the amount of fly rock produced. Orr explains that the void identification capability mentioned can also improve safety by "alerting operators of heavier equipment to stay away from unstable ground, which they can fall into." Improved explosives management helps to reduce misfires and hole failures, and the ProVision system's high-precision navigation provides accurate collar location, which ensures better compliance to plan while significantly reducing rework and field surveying.

Stratification can also reduce blasting back-break and slope conditions by allowing for more precise charge placement; this helps to ensure the accuracy, stability, and integrity of pit walls. Knowing the various material compositions (derived from the energy and hardness levels) also allows for more control around geotechnical structures, and helps preserve the pit floor grade, as operators are less likely to drill past the next bench or leave a toe behind.

Two large mines in Brazil reduced their explosives consumption by more than 20% per year after integrating the ProVision Drill system with the Drill Hole Stratification module on 20 of their drill rigs. The mines looked to Modular for assistance in meeting the following objectives:

- Improve efficiency at the crusher by improving rock fragmentation
- Reduce drill and blast operational costs
- Improve loading efficiency.

Modular's engineers observed that the mines' drill hole spacing was often inconsistent and misaligned to the planned pattern, which was negatively impacting the mines' blasting and fragmentation efforts and producing inconsistent rock sizes.

ProVision's real-time depth versus design and high-precision navigation capabilities provided a clear solution to the mines' drilling issues, and significantly improved consistency of the drilling patterns while also reducing under-, over-, and re-drilling events. Likewise, the Drill Hole Stratification module optimised the mines' fragmentation efforts and subsequent bench designs.

Before implementing the ProVision system and Drill Hole Stratification module, the mines reported an average usage of 0.0625 lb/t of explosives. After implementation, explosives consumption was reduced to only 0.049 lb/t while significantly improving fragmentation. This improvement in fragmentation despite a reduction in explosives is a clear example of a mine achieving optimal blasting performance - and the nearly 22% reduction of explosives produced an annual cost saving of almost $800,000 across each mine's drill rigs. The mines also improved their crusher performance, as the better-fragmented material resulted in more efficient crushing without the downtime caused by larger rocks. Improving fragmentation results also improved the mines' loading efficiency for both shovels and trucks, as shovels achieved digging ease on a flatter grade, and trucks could now carry consistent, even loads without unnecessary wear to teeth and other mobile equipment components.

VARI-STEM's patented GEAR design prevents plug collapse in undersized holes or when forced over jagged rocks. It makes the plug detonator cord (tube or wire) friendly. The numerous vertical grooves on the outside diameter of the plug prevent the detonator cord from being crushed, nicked or pulled into the drill hole during insertion. (The cord will simply slip into one of the vertical grooves.). It also gives structural strength to the plug and allows a compressed hold when used in air decking. These plugs should be inserted point-down. Using a standard loading/charge pole, simply push the plug to the ANFO or emulsion

In the paper *Stemplug blasting application at EGAT-Mae Moh Lignite Mine: On-the-field Testing* by P Bunnaul et al, stem-plug blasting tests were studied in comparison with the blasting technique currently used for overburden blasting at Mae Moh lignite mine in Thailand. Blasting vibration, fragmentation, shovel and crusher performance were monitored. Stem-plug blasting provided lower vibration and better fragmentation. Higher performance of both shovel and crusher could be achieved with stem-plug blasting. The truck loading rate of the shovel was found to increase by 22.6%. Overburden crushing rate increased by 37% even though it was not run at full load. "It could be expected to be much higher if the crusher was run at full capacity," the authors report.

The study also found vibration reductions of 37.4-63.2%.

Maximum blast containment means greater fragmentation and micro-fractures, with more tonnage processed at less cost. Following orebody fractures created by the explosive shock waves, the Varistem improves expanding gas containment. The greater the gas containment time within the ore mass fractures, the better the fragmentation. Expanding gas fragmentation is substantially cheaper than mechanical breakage.

VARI-STEM says "the Varistem reduces processing costs, with the Varistem achieving up to a 25% increase in fragmentation. Independent studies also show the Varistem can increase blast patterns 10% or more, with the same fragmentation for major savings in drilling and explosive costs. The very low cost Varistem is the most efficient means of reducing costs in blasting and processing."

Blast monitoring

Choosing the right set of monitoring solutions for your mine is a daunting task. Motion Metrics has created a new resource to help miners decide if its products are right for their operation. The Motion Metrics Resources page contains a variety of technical brochures, product case studies, and trade publication articles that explain the problems monitoring solutions aim to solve and showcase the safety and productivity benefits customers can achieve by implementing its systems.

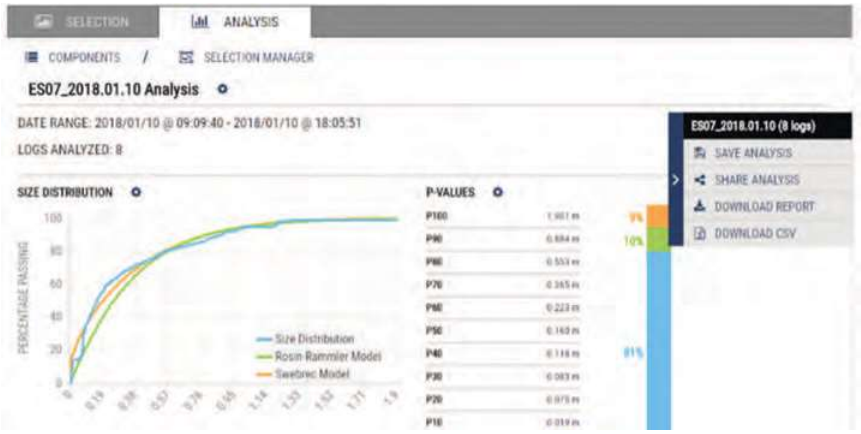
For example, there is an article that compares PortaMetrics™ to traditional methods of fragmentation analysis. PortaMetrics is a ruggedised portable fragmentation analysis tool that does not require any reference scaling objects. Motion Metrics says "it is a safe and accurate alternative to traditional fragmentation analysis methods."

Early this year, Motion Metrics released a new and improved version of MetricsManager™ Pro! This is a major release with several significant features, primarily focused on boosting fragmentation capabilities.

Among the features is a new segmentation algorithm that boosts fragmentation performance. The new algorithm yields a 5-10% accuracy improvement in P80 and P100 values, and performs ~four times faster than its predecessor, the company reports.

Another feature Motion Metrics has added is the ability to download fragmentation data as a CSV file. This capability will grant users greater flexibility to analyse data from Motion Metrics systems and integrate it with existing mine software.

The newest iteration of MetricsManager Pro also includes an experimental fragmentation recommendation engine. This time-saving tool tries to select logs that are suited to fragmentation; it also provides options for



Users of Motion Metrics' MetricsManager can now download fragmentation data as a CSV file via the dropdown menu

selecting logs that show fines, boulders, empty buckets, or downtime. The company reports that "on the test data set, this experimental engine was already 85% accurate; as with all learning algorithms, we can achieve higher accuracy with more data."

Additionally, users are now able to select a default home page to redirect to when they login. This allows mine staff to customise their user experience based on individual workflows.

A paper presented at this year's SME Conference in Minneapolis, *Fast rock segmentation using artificial intelligence*, by M. Ramezani and colleagues at Motion Metrics looks to the future. "Image-based rock fragmentation sensing in mines includes an important rock boundary delineation step, commonly referred to as rock segmentation."

The paper presents an artificial intelligence (AI)-based solution to this challenge. The proposed technique encodes prior knowledge of previously analysed images into mathematical/statistical models. Human-labelled images are used as inputs to train neural networks through an optimisation process. The networks can then be used in real time for rock delineation.

To build the models, special deep artificial neural networks are used as a pixel classifier. The proposed classifier labels each pixel (edge, rock or fine) by analysing a plurality of pixels within the image. Advances in machine learning allow the network to contain many parameters. The increased number of parameters is a strong factor in the classifier's ability to correctly classify each pixel.

Deep learning-based segmentation, combined with 3D imaging followed by post processing, provides a unified fragmentation sensing solution. Results from automatic segmentation are compared to human labelled segmentation using the percentage passing curves for 64 rock images.

The authors conclude that "this approach attempts to mitigate the challenges facing rock boundary delineation caused by variations in material texture, suboptimal lighting conditions, and the unknown size and shape of rocks. In the proposed technique, models were built based on training inputs, ie pixels within rock images, and used to make decisions for segmentation of test images. Results showed that fast and accurate automatic segmentation can be achieved using this technique."

Carlson EMEA, a wholly-owned subsidiary of Carlson Software, has acquired the mining (Quarryman, Boretrak, C-ALS, Void Scanner), marine mapping (Merlin), and laser module (ILM) product lines previously owned by Renishaw plc. Carlson says this acquisition will enhance its

existing product portfolio for the benefit of its customers and for former Renishaw customers. "Carlson has focused heavily on the mining industry with software, hardware, and machine control solutions since 1984," notes Bruce Carlson, President of Carlson Software. "These additional key hardware products for measurement and mapping of surface and underground mines greatly enhance our product offerings and will allow us to expand our focus more fully to the ore, quarry, and blasting industries."

Hydraulic breakers

Of course if a blast does not go well, there is the problem of oversize material, and that's one of the many applications for hydraulic breakers in mining. One of the great names in that field is Rammer, which is celebrating 40 years this year. The success was born in Finland and is now a global brand, part of Sandvik, one of the world's largest producers of capital equipment. The growth, success and popularity of the Rammer brand has been built upon a foundation of innovation and 40 years on, the company continues to innovate. It has continued to enhance its position as a world-leading hydraulic hammer brand.

Last year saw Rammer introduce its latest, largest hydraulic hammer, the Rammer 9033, which replaces the highly successful Rammer 7013 and benefits from a number of key changes and improvements, many of which have been proven in smaller Rammer hammers. These include:

- A 20% wider carrier weight range than the Rammer 7013
- A 22% higher input power which significantly increases impact rate and productivity compared to its predecessor.

These customer-friendly improvements have been achieved by equipping the new Rammer 9033 with many of the key features recently applied to other models in the Rammer Large and Medium ranges. "Our engineers have applied lessons learned on other hammer models to place this Rammer hammer at the very top of its class," says Rammer General Manager Rafa López. "The Rammer 9033 completes the successful Rammer Large hammers family by replacing the aged 7013 with a modern design that extends some of the specifications such as carrier range allowed and tool diameter."

The new Rammer 9033

Weighing in at 7,000 kg, the Rammer 9033 is suitable for carriers in the 60 to 120 t operating weight range. Impact rate on the long stroke setting rises from a maximum of 450 blows per minute to 520, while maximum oil flow rises to 460 litres per minute against the 400 litres per minute on the 7013. Input power is up from 113 to 138 kW.

Stroke length and Idle Blow Protection can be easily adjusted to allow the unit to be purpose-matched to individual applications. The long stroke setting uses a lower blow frequency for optimum breaking in hard materials, such as granite, while the short stroke setting delivers higher blow frequency which is ideal for softer materials, such as limestone. The Idle Blow Protector on/off selector allows the operator to easily adjust the working mode to protect against idle strokes.

The new model uses long-life, high-tension VIDAT tie rods for improved reliability and lower operating costs. The tool-retaining pins are locked by simple, reliable rubber rings, while the surface of the lower tool bushing has been specifically designed to provide longer tool life.

The 9033 also becomes the latest (and final) model in the Rammer Large Range to benefit from the addition of the Ramvalve overflow protection system. This monitors the oil flow through the hammer. If the oil flow exceeds the pre-defined setting, the valve adjusts the flow to a very low level and drops the hammer's impact rate. The Ramvalve resets after the hammer re-starts with a correct oil flow. This highly effective system provides excellent protection against accidental overflowing and overpressure, enhances hammer's reliability, and offers improved protection against oil spills.

To further extend the working life of the Rammer 9033 it is offered with three greasing options: a centralised manual option; carrier-mounted Ramlube I automatic greasing; or Ramlube II, which utilises a cartridge mounted on the hammer to automatically deliver optimum levels of lubrication for greater wear protection and a longer service life. It also comes equipped with the Ramdata II service indicator that allows operators and service personnel to monitor and log vital service and maintenance information to further minimise downtime.

An important delivery of a Rambooms boom system with Rammer hammer to South Deep gold mine is covered in the *World Prospects* section of this issue. ***IM***