Having a blast

Ailbhe Goodbody looks at blasting technologies in surface mining, and the latest developments in ultra-high-intensity blasting and the elimination of NOx fumes

"Blasting is a dynamic process that constantly needs to be refined based on the ground conditions"

The approach to blasting at a mine site is determined by the mine owner's requirements. Typically, for waste areas in a pit the objective will be to remove the waste as efficiently as possible for the cheapest cost per tonne. Orebodies will have more constraints imposed to ensure a specified level of fragmentation is achieved without compromising dilution of the ore.

The factors that determine which blast pattern designs are used can be complicated. When designing blast patterns, some of the significant factors to consider include:

- The fragmentation requirements for loading, hauling and crushing;
- The drilling and loading equipment available;
- The energy delivered by the explosives;
- The type of rock being blasted and its physical properties and strength;
- Geological features and anomalies which may exist in the rock mass;
- The bench heights;
- Wet or reactive ground considerations;
- Proximity to sensitive receivers such as infrastructure, heritage sites and fibrous areas; and
- Access to and topography of the work area to ensure that a safe environment is provided for drilling and blasting operations.

An MPU loading a blast pattern on a coal mine in Queensland, Australia
Photo: Action Drill & Blast

Action Drill & Blast says that drill patterns, spacing and depths are determined by considering all the constraints present while striving to exceed the physical and commercial objectives of the blast.

The blastability of the rock is dependent on the pre-existing structure in the rock mass, its density and, to a lesser extent, its strength. The higher the blastability index, the more difficult the rock is to fragment by blasting.

Tony Rorke, director, blasting technology at BME, explains: "It is important to know what the rock is that is being blasted, but more importantly it is necessary to know how many cracks nature has put into the rock before blasting."

Different combinations of bulk explosives can be used for various reasons. For example, wet ground conditions require a water-resistant product to successfully initiate, and if water is present in the blasthole then the bulk explosive will need to have the ability to displace water when loaded from the bottom of the hole upwards.

Variable-density products allow the energy density of the product to be optimised to provide better fragmentation with a higher velocity of detonation (VOD), and a higher ammonium nitrate (AN) content provides a cheaper product that produces increased gas volumes with increased heave characteristics.

Rorke says: "For example, brittle rocks may need an explosives product with a high VOD, compared with more friable rock that would respond better to an explosives product with a low VOD."

Explosives companies spend a large proportion of their research budgets formulating explosives that provide the right combination of energy and reaction rate (VOD) for different rock types.

BETTER BLASTING

Better blasting improves downstream mining processes in a number of ways. It results in increased dig rates and increased crusher throughput, along with reduced ground-engaging tool (GET) and maintenance costs. In addition, it accelerates schedules and reduces overall mining-project durations.

An Action Drill & Blast spokesperson explains that the results of good blasting have a compounding effect on downstream processes, which increases the profitability of a project.

Blasting systems can use different types of detonators, which are generally mechanically or electrically initiated. Electronic detonators can provide huge benefits in applying novel and effective approaches to sequencing a blast. Examples include the protection of coal in surface overburden blasts.

Rorke suggests: "The most important issue to bear in mind is that more explosive energy per unit of rock being blasted remains the most effective way of improving downstream productivity and thus saving money."

For example, BME explosives can be initiated with any of the appropriate commercial initiation systems that are available on the market. Rorke notes: "The important criterion is that the booster used has sufficient energy to initiate our explosives, as is necessary for all commercial explosives."

However, BME also supplies AXXIS electronic detonators, which it says provide big benefits in initiating the explosives charges in the designed sequence.

Rorke says: "AXXIS electronic detonators are accurate and provide flexibility that enables explosives engineers to design complex initiation sequences that afford wall control, dilution control, vibration control and required heave. These electronic detonators are also useful in providing control in environmentally sensitive blasts where vibration and air blast need to be contained."

To improve cast blasting by approximately 30% at Yancoal's Middlemount coal mine in Queensland, Australia, Action Drill & Blast conducted several blasts trialling electronic detonators and adjusting other variables to determine the most successful outcome. Action ►

Drill & Blast says that by using electronic detonators with multiple primers within the hole, adjusting timing between holes beyond traditional practices and modifying bulk product formulations, it was able to achieve its client's improvement target.

Blasting and fragmentation can be predicted somewhat by experienced personnel, but blasting is a dynamic process that constantly needs to be refined based on the ground conditions on hand. Prediction of blast fragmentation is a difficult science because the rock is so complex and cannot be easily defined; geological characteristics can change significantly over very small distances.

The Action Drill & Blast spokesperson notes that just because a blast worked well on one side of a pit, this does not ensure that the same parameters will work in a different location. The company endeavours to obtain all the information available, from visual inspections, previous blast results and drill quality assurance data, and refine the blast design to suit. It can then use blast-modelling programs to simulate and analyse various different designs to determine the optimum design for the job on hand.

Tony Rorke, director, blasting technology at BME, with the AXXIS electronic detonator equipment

At this stage, most explosives companies and mines globally use simple equations that can predict blast fragmentation results reasonably, but not accurately.

Rorke explains: "Much research and money is being committed to complex numerical models that can predict fragmentation and heave accurately, but the problem is dependent on defining the rock accurately, which is not an easy task."

THE FUTURE OF BLASTING

Improving safety is always a big trend in blasting. Reducing the exposure of personnel to the risks of blasting operations will encourage technological innovations and product development.

In addition, developing a product which can have its density and explosive energy properties changed almost instantly during the loading process would allow deep blastholes to be loaded in a way that allows the areas requiring higher explosive energy to be targeted without subjecting the weaker areas to the same explosive energies.

The development of mobile processing unit (MPU) trucks with GPS guidance and remote operation could also be options.

Rorke adds: "Electronic initiation systems coupled with effective blast-design software are the biggest technological developments that mines are mostly converting to."

Due to decreasing commodity prices and reduced profit margins, the future of blasting in mining will be focused on delivering the most cost-effective solutions.

Blasting without NOx hazards

CRCMining is developing cutting-edge blasting solutions to eliminate the serious hazard of post-blast nitrogen oxide (NOx) fumes from blasting of coal overburden. The industry-driven centre for global mining research and innovation based in Queensland, Australia, states that this will significantly reduce risk of workplace, health, safety and environmental issues.

Post-blast NOx fumes from coal overburden blasting seems to be an industry-wide problem; it occurs in a variety of geological conditions and with the use of a variety of bulk AN-based explosive products. Nitrogen oxide and nitrogen dioxide are toxic gases that can cause serious health risks to personnel exposed, and can also adversely affect the environment in various ways.

Increased scrutiny of post-blast fume generation and risk control has had a direct impact on the mining industry's licence to operate. However, CRCMining states that research and development into mining explosives since the introduction of AN and emulsions has been at a standstill for more than 60 years.

In partnership with the School of Mechanical and Mining Engineering at the University of Queensland, CRCMining is developing solutions that could potentially eliminate the NOx hazard. CRCMining states that its way to replace AN is a step-change which could offer different possibilities to mining companies, particularly with regards to procurement and security of supply.

The current project aims to develop an explosive formulation that will match the rock-breakage requirements of soft and saturated ground conditions, and also substitutes the use of AN as the main oxidising agent, which will completely eliminate the potential of NOx fumes.

Dr Italo Onederra, project leader, explains: "This is a very exciting project as it focuses on the elimination of the NOx hazard by applying scientific principles rather than procedural methods, which are prone to variability. Preliminary detonation test results recently published at an international conference are very encouraging. If the explosive delivers the expected outcomes, there is no doubt that Australia will be at the forefront of mining explosives' innovation."

CRCMining's project aims to develop an explosive formulation that substitutes the use of AN as the main oxidising agent, eliminating the potential of NOx fumes

Other future benefits may include the elimination of the potential risk of AN discharge into groundwater systems. There could also be improvements in overall community safety associated with manufacturing and transportation processes. The development process will incorporate the use of sustainable and renewable fuel sources into the testing programme.

The Australian Coal Association Research Program (ACARP) is currently funding the first stage of development of this project, led by Dr Onederra and Miguel Araos. CRCMining is seeking potential mining partners to launch the next stage of the project and secure trial sites.

Ultra-high-intensity blasting

A new blasting technique has been developed by a team of researchers at Orica, which has already demonstrated its potential to significantly enhance mill throughput while saving costs at mine sites.

The new ultra-high-intensity blasting (UHIB) process applies chemical energy to assist the comminution process in ways previously thought to be impossible.

With more effective blasting, ore is reduced into smaller particles, or fragments, before the costly and energy-intensive load, haul, crushing and milling stages.

By focusing on fragmentation through effective blasting, the milling operation stands to benefit from increased throughput, reduced production costs, a potential reduction in capital costs, lower greenhouse-gas emissions per tonne and improved social licence to operate. The financial savings alone can be tens of millions of dollars annually.

THE 2014 CEEC MEDAL

The Coalition for Eco-Efficient Comminution (CEEC) awarded its 2014 CEEC Medal to Dr Geoff Brent and the Orica research team that developed the UHIB technique. The CEEC is a high-level think tank that aims to identify and promote more efficient comminution practices.

Brent and his Orica colleagues, Dr Peter Dare-Bryan, Stuart Hawke and Michael Rothery, describe the UHIB technique as a new paradigm in mining, because it has the potential to increase mine production and profitability while reducing energy consumption and greenhouse-gas emissions.

Ian Smith, CEO and managing director of Orica, says: "This research demonstrates Orica's commitment to the development of resourceful solutions to improve mine productivity. The use of electricity to mill ore is usually the largest consumer of energy on a mine site and ore comminution constitutes a significant percentage of electricity consumed worldwide.

Trials have shown that UHIB blasts can control flyrock and vibration better than conventional blasting methods

A CLOSER LOOK AT UHIB

Researchers and blast engineers at Orica have long recognised that improving rock fragmentation during blasting can deliver substantial gains in the productivity of excavators and the ►

"Improving rock fragmentation during blasting can deliver substantial gains" downstream crushing and grinding processes. Many industry 'mine to mill' studies have identified that such gains could be achieved through increased blast energy, or powder factors. In essence, blasting can be considered the first step in comminution.

Over a number of years, Orica has worked closely with industry partners including the Australian Mineral Science Research Institute (AMSRI). Modelling by the University of Queensland showed that theoretically, if explosive energy was increased beyond common accepted practice by four or more times, then a step change in mill productivity and power reduction was possible.

The limiting factor, however, has been that conventional blasting techniques have not been able to control the rock movement created from significantly higher energies, thus the industry has been limited by safety and environmental issues such as flyrock, unacceptable vibration, airblast and wall damage.

UHIB safely utilises blast energies or powder factors several times higher than normal in a novel design. The design involves blasting the rock in two layers within a single blast event, initiated with state-of-the-art electronic blasting systems.

Brent states that with UHIB, an upper layer is blasted first using conventional powder factors and the broken rock is allowed to fall to rest before the lower layer is then initiated with ultra-high powder factors.

He explains: "In effect, the broken rock from the upper layer provides an effective buffer or blanket to contain the energy in the lower layer. This buffer avoids flyrock while allowing us to use powder factors in the lower layer that are up to five times higher than those used in conventional blasting, delivering much more intense fragmentation of the ore.

"Meanwhile, independent studies have found that increasing these powder factors in the range of 2-5kg per cubic metre of rock can produce much finer rock fragmentation and increase mill throughput by 20-40%."

Brent adds that blast modelling and field trials have also shown that control of surface ejection and vibration levels were better with the UHIB method. He comments: "These results are quite remarkable, given the large increases in explosive energy, and reveal that highwall damage as well as vibration and potential damage to key mine infrastructure can be safely controlled when using this method."

FIELD TRIALS

Over the past four years, Orica has been trialling UHIB at copper mines in Latin America. Brent declares: "The trials have shown that blasthole patterns as tight as 4m x 4m, with hole diameters of 250-300mm, can be drilled, loaded and fired successfully, and no explosive or initiator malfunctions have been observed.

"They have also shown that UHIB blasts can control flyrock and vibration better than conventional blasting methods. The early results from the field trials indicated that rock fragmentation from UHIB was finer."

For example, a fragmentation vision system installed at a mine's semi-autogenous grinding (SAG) mill feed recorded a seven percentage-point increase in the size fraction under 25mm entering the mill from the UHIB trial section. Another series of full-scale production blasts at a mine in Central America showed increases of 10-15 percentage points in the size fraction under 50mm.

DOWNSTREAM BENEFITS

Brent states that the implications of UHIB for mine productivity and the environment are significant. He explains: "There's a worldwide trend to decreasing ore grades, so UHIB is particularly useful in complex and lower-grade orebodies because it may elevate them to become practical and economically viable to extract.

"The environmental benefits stem from the fact that emissions in open-cut mines from diesel and electricity are typically 100 times greater than the emissions from explosives.

"Independent modelling has revealed that our new UHIB method has the potential to reduce overall energy consumption and cut CO_2 emissions caused by grinding by up to 30%. This highlights the potential that UHIB offers for an exciting new era in blasting.

"By using far more explosive energy safely and with control, this new technology can enhance mine productivity and reduce overall energy consumption and greenhouse-gas emissions, improving the sustainability of mining well into the future."

THE FUTURE OF UHIB

UHIB is being introduced progressively at a number of mine sites around the globe. The new technology is widely applicable across mining sectors, including gold as well as base metals such as copper, lead, zinc and certain types of iron ore.

Steve Boyce, chief mining engineer at Orica who heads up the Mining Applications team that developed the technique, says: "We believe the adoption of the UHIB technique will increase as energy costs rise and the cost of building new mineral-processing plants increases.

"It is most applicable in regions where energy is expensive and at mines where the strength of the ore has been underestimated and milling capacity is constrained.

"The method is easily applied, but uses highly advanced technology that brings about a step change for the mining industry, particularly at this stage in the metal price cycle when we need to do more with less."

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