Mastering the Art of Blasting

E&MJ looks at key advances and future opportunities in underground blast design and initiation

By Carly Leonida European Editor

Orica's WebGen 200 Underground Pro wireless initiating system removes personnel from harm's way during blasting. (Photo: Orica)

Over the past decade, the underground mining industry has witnessed some remarkable advancements in blast design and execution driven by factors including the increasing geotechnical and geological complexity of orebodies, the need to access deeper and larger deposits, evolving societal expectations, and a general shift towards expanding underground operations due to resource scarcity.

Angus Melbourne, Chief Technology Officer at Orica, explained: "Some of the most important developments that have shaped this field include improved blast modelling and simulation. The use of advanced computer modelling and simulation software has become more prevalent, and these tools allow engineers to accurately predict blast outcomes, optimize blast designs and assess potential risks. By providing precise control over parameters such as hole spacing, burden, and timing, these tools contribute to better fragmentation, reduced energy consumption, and improved overall performance.

"Progress has also been made in enhancing the performance and safety of explosive formulations; the development of energy-efficient and water-resistant explosives has contributed to better rock fragmentation and reduced environmental impact."

As in many other areas of mining, automated equipment and processes are sought after driven by the need for better safety, productivity, and sustainability. These technologies reduce the need for humans in hazardous areas and boost safety during blasting.

"The integration of digital technologies, including data analytics, artificial intelligence (AI), and remote monitoring systems, has also improved operational efficiency and decision-making in blast design and execution," added Melbourne. "Real-time data collection and analysis enable quick adjustments to blast designs and enhance overall productivity.

"Overall, our deepening understanding of rock formations, encompassing their geophysical and geochemical properties and how blasts propagate across diverse rock compositions, has been instrumental in advancing underground blast design and execution. This enhanced understanding has enabled us to develop targeted solutions that address the unique challenges posed by a wide range of geological conditions."

Wireless and Automated Blasting

In recent years, Orica has introduced several technologies as part of its Orebody Intelligence portfolio to increase geospatial precision and geophysical measurement accuracy in exploration and resource definition drill holes.

"Instead of relying on conventional wireline methods, our DRILLMax and DRILLHub technologies provide real-time measurements while drilling is in progress," said Melbourne. "Real-time data acquisition brings substantial benefits to the decision-making process. Not only does it reduce the time required to receive critical geological information, but this rich data set also enables key decisions to be made with a greater level of confidence and accuracy."

Continued development of these technologies will soon extend their application to blasthole drills too, delivering data that enhances decision-making capabilities during mine production.

Blast design plays a vital role in optimizing ore recovery and minimizing issues such as underbreak and overbreak through optimal application of blasting energy.. Recent technological advancements have enhanced the scope and speed of computer-aided design, analytics and modelling, leading to improved blast performance. Orica's SHOTPlus software provides engineers with the tools to design and execute blasts while enabling other Orica products, such as the 4D bulk emulsion delivery system, and WebGen wireless blasting technology.

Wireless blasting is a relatively new but important addition to underground mining as it can improve both safety and operational performance. A key benefit is removal of the need for individuals to enter draw points or brows to connect and charge blastholes by pre-charging entire stopes or sublevels and remotely initiating sections. Wireless blasting can also enhance recovery by allowing pillars and crowns that would otherwise be left untouched to be blasted, and it can increase productivity as entire stopes can be charged in a single campaign. Additionally, wireless provides for innovative blasting sequences that maintain broken ore at the drawpoint of wide-span stopes, thus minimizing the need for less productive tele-remote loader operations.

Orica's WebGen wireless initiating systems allow firing signals to be sent directly to an in-hole receiver, removing the need for wires or signal tube in or between blastholes. Launched in late 2022, WebGen 200 Underground Pro (the second generation of WebGen) is suited for underground production blasting, while WebGen Underground Dev is designed for mechanical assembly and will enable the automation of underground development loading with Avatel, the world's first mechanized, wireless development charging equipment.

Avatel was jointly developed by Orica and Epiroc through a partnership which commenced in 2019, and the solution gained commercial status in 2022. It has the capability to remove debris from lifter holes, clear blocked blastholes, deploy a WebGen wireless primer then load each blasthole with a specified energy through automated string loading.

Melbourne said that, with mines around the globe trending toward deeper and larger underground operations, innovative processes such as this will be critical to supporting industry growth.

"A longstanding challenge for underground mines has been the requirement for time consuming and costly controls to manage safe access to the development face, particularly for charge crews," he explained. "Avatel has the potential to eliminate these constraints by removing personnel from the hazard. Enabled by the WebGen wireless initiating system and built on the foundation of Epiroc's M2C Boomer, Avatel was designed to require only one operator to fully prepare and charge the face from the safety of an enclosed cabin, several meters away from face."

Optimizing the Mine-to-mill System

The application of machine learning to upstream orebody intelligence data for automating blast domains has also sped up and enhanced the blast design process, as well as optimizing blast performance.

"A critical technology enabler that further leverages this capability is our Integrated Extraction Simulator (IES) modelling tool which was developed by the CRC ORE consortium," said Melbourne. "Its capabilities encompass simulating and optimizing the entire process, starting from the orebody and extending to the final production stage. We're currently developing operational software interfaces to IES, facilitating blast simulation, optimized blast design generation, and validation of actual versus predicted plant performance. This will transform the traditional mine-to-mill optimization approach from a static and laborious project exercise into a sustainable and integrated operational workflow."

Melbourne believes that AI will transform underground mining in the coming years through intelligent blast design, blast optimization and sequencing. "IoT devices will play a crucial role in obtaining accurate measurement data," he said. "Furthermore, the industry will continue to see a growing emphasis on interoperability between software and hardware, facilitating comprehensive integration and advanced data analytics."

Moving forward, Orica is exploring new applications for its WebGen technology and, in doing so, it has identified a growing need for increased sleep times for bulk explosives in various operating environments, including reactive ground.

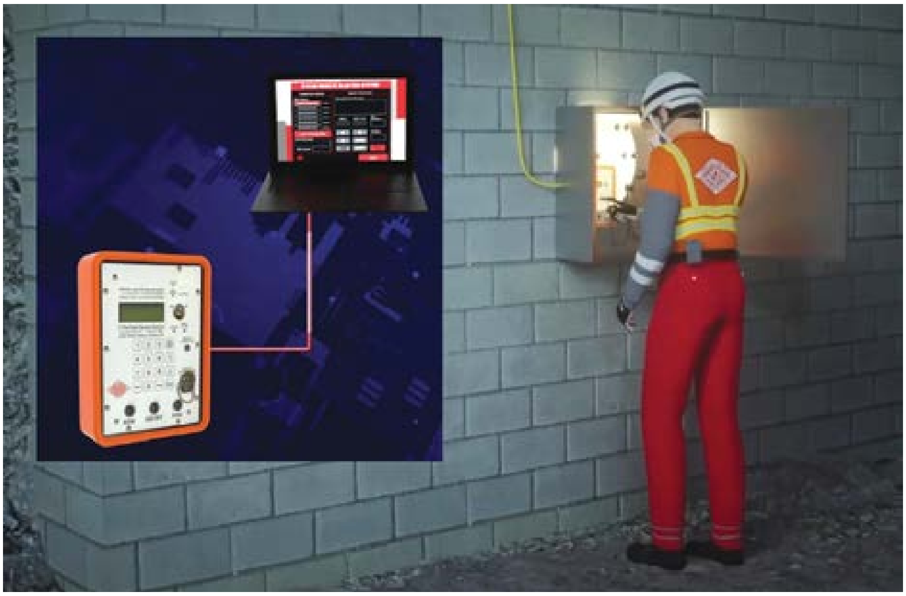
Blast Design for the 21st Century

Contemporary blast patterns have been built upon the foundational concepts of empirical modeling and anecdotal legacy experience with the given rock mass. The underground blast designs utilized today begin with a basic understanding of design parameters supported by proven analytical data and good-blasting practices. This method will often result in the same initial blast design for multiple projects, despite their vastly different rock mass characteristics.

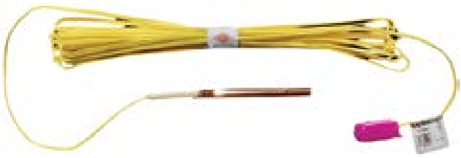
Justin Banks, Director – Underground at Dyno Nobel, USA, explained: "Once established and proven safe and effective, the blast designs are then adjusted based on the mine's desired outcomes (fragmentation, ground vibration response, mitigation of backbreak, muck placement, dilution etc.) and the response of the in-situ material. This step may require extensive trial and error, but the core competency of blast design remains intact from the preliminary empirical-driven model."

While the principles of blast design have stayed relatively consistent over the past decade, the use of electronic detonators has become more prevalent.

"As mines become larger, deeper, and more complex, the flexibility and safety benefits of utilizing electronic detonators in conjunction with a centralized blasting system will address increasingly demanding environments," added Banks. "Miner safe-



With centralized blasting equipment, such as E*STAR CUBE from Austin Powder, operators can now initiate multiple blasts from the surface with zero personnel in the mine. (Image: Austin Powder)



The E*STAR tunnel detonator from Austin Powder. (Photo: Austin Powder)

ty will always be paramount. To this end, future trends and technological advancements will continue to address worker safety as orebodies become more challenging to access. The market has already seen dedicated partnerships between various supply elements to increase worker safety and maximize production efficiencies.

"Wireless electronic detonators, autonomous or semi-autonomous bulk explosive loading and centralized blasting systems over a variety of communication backbones are some examples of removing/mitigating the human risk element from underground blasting operations. This trend is expected to continue and may represent standard operating procedures soon."

Paul Kuznik, DynoConsult Manager – Eastern Canada at Dyno Nobel, Canada, added that mining customers are showing more interest in wireless detonators.

"Unstable ground, various mining techniques and/or complex orebody configurations sometimes don't allow for safe return to a previously mined area," he told *E&MJ*. "That's when preloading rounds helps in maximizing safety and ore recuperation. Dyno Nobel has a proven and tested product to support customers in those instances called Cyberdet."

Fragmentation is another subject which remains a top priority. Mine optimization, including blasting, mucking, hauling and crushing plays an important role in making economical gains and in processing ore more efficiently. Better fragmentation leads to faster cycle times and less dilution, allowing each operation to run more efficiently.

"Geotechnical surveys and rock characterization go hand-in-hand with successful drilling and blasting," said Kuznik. "New technologies and software allow engineers to design a blast and run simulations to better predict end results. It's not always possible to foresee all scenarios, but modeling technologies allow us to test different approaches and analyze their outcomes. For example, through better understanding the geology, the risk of uncontrollable fly rock can be evaluated beforehand without an unsafe energy release into the immediate environment. Additionally, safe evacuation distances can be established, and proper mitigation measures taken to protect equipment in close proximity to the blast, or simply by removing all risks from the immediate area."

He added that drones or 3D scanners, paired with deviation probes, borehole cameras, precise distance measurements using GPS are key to building a detailed model for simulation software to predict blast outcomes.

Software for Precise Control

Mark Ganster, Manager Blasting Technology – Europe at Austin Powder, agreed with his peers that the advent of advanced blast design software has fundamentally changed the industry's capabilities in this field. Underground blast design and control are fast becoming something of an artform.

"One of the most important advances we've seen in underground blast design over the past decade has been the introduction of software programs, such as Austin Powder's Paradigm, which provide 3D modeling of charge concentrations, energy contours, damage probabilities, timing sequences and fragmentation prediction," he told *E&MJ*. "Further, with centralized blasting equipment, such as the E*STAR Centralized Underground Blasting Equipment (CUBE), operators can now initiate multiple blasts from the surface with zero personnel in the mine."

Used in conjunction with Austin Powder's explosives and boosters, the company's E*STAR electronic detonators and Shock*Star detonators recently saw success at an underground gold and silver mine in Chihuahua State, Mexico. The mine is divided into two sections: one containing a disseminated orebody which is mined from sub-level stopes using the long drilling fan mining method, and the other a narrow vein deposit which is mined using a variety of methods, including long-hole blasting and cut and fill.

Drill patterns for the cut and fill blasts usually involve around two hundred holes, each with a diameter of 1.9 in. (48 mm) and length of 14 ft (4.3 m). The holes are distributed in rows along the stope length with a burn cut drilled at the beginning to create an open face. The burn cut is then detonated using E*STAR Detonators, and the production rows next to the cut are initiated using Shock*Star Detonators and detonating cord.

For this project, it was necessary to load and blast 500 holes. The stope was divided into three sections, each consisting of a burn cut and a different number of production hole rows. The mine required minimum dilution between vein blocks, but still required the whole stope to be blasted in a single event. The use of electronic detonators in all holes was not possible due to cost, so to minimize the risk of a misfire, E*STAR Electronic Detonators were chosen for the burn cuts and Shock*Star for the production rows. This combination allowed versatility in the timing design and using a longer time between burn cut holes generated better displacement and formation of the free face.

The blast was a resounding success. No misfires or live explosives were left along the stope, all detonators (electronic and non-electric) were started and performed correctly, and the burn cuts performed well, generating an optimal free face for the production rows. The blast broke more than 2,200 tons (2,000 metric tons) of high-grade ore with a single firing signal, achieving a consistent fragmentation of P80 (5-in. to 10-in.).

"Our E*STAR Electronic Initiation System is continually evolving as technology and information become available to improve overall blast design, product selection and safety," said Ganster. "Austin Powder is further developing its suite of modeling software to include a solution for blast design and modeling of drift blasts for both mining and underground infrastructure projects. And we continue to improve the E*STAR CUBE to be compatible with the latest technologies.

"In time, automation of the complete blasting process, from automated drilling to an automated charging process for explosives, will reduce the number of people exposed to risk and increase productivity while reducing costs and allowing for access to deeper orebodies. New products and technologies, such as the Red D GEM gassed emulsion equipment and the E*STAR Tunnel electronic initiation system will help to reduce powder factors and improve wall stability, overbreak control and safety."