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MINING & QUARRY WORLD

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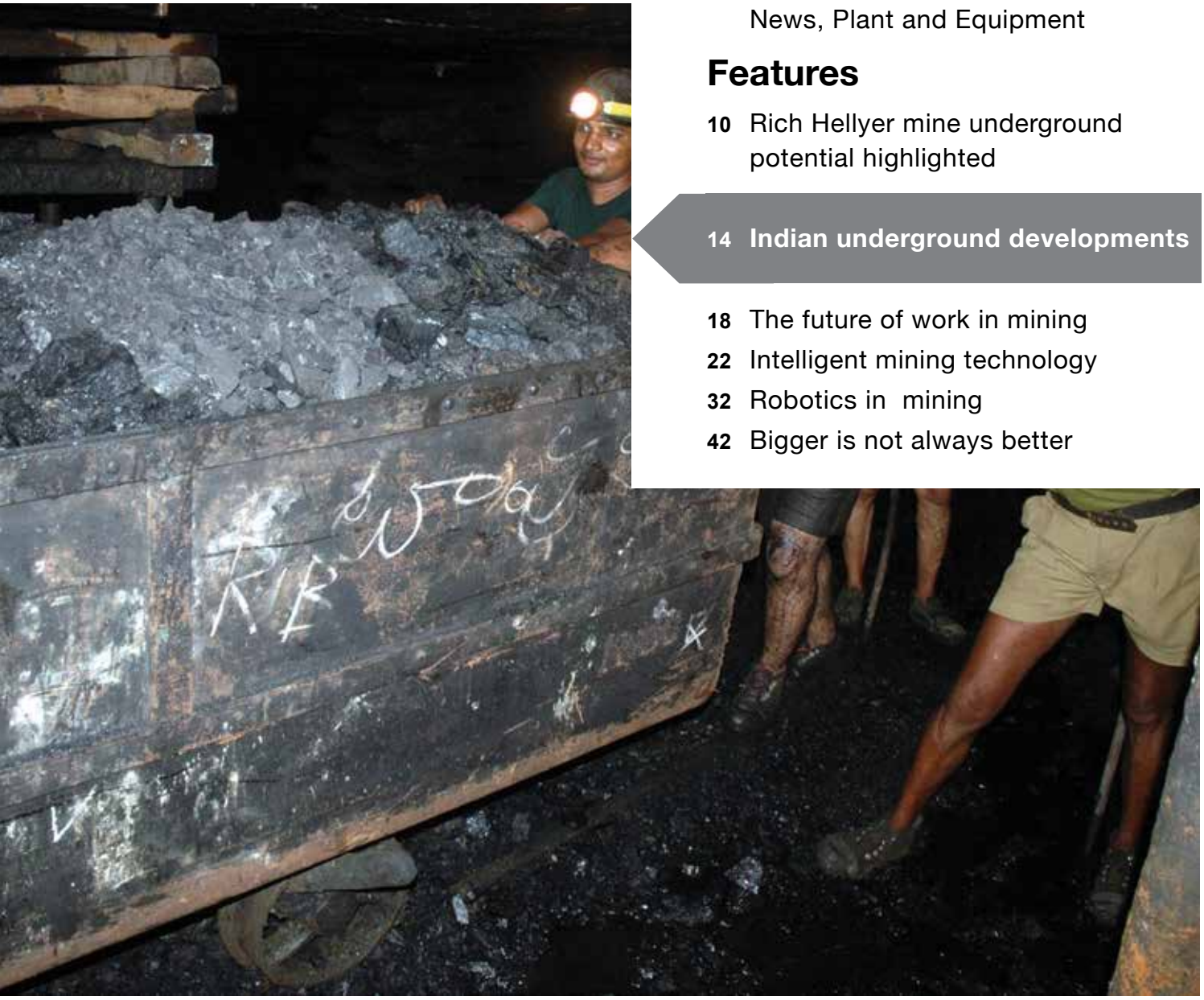

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DSI Underground supports the Alto Maipo Hydroelectric Power Plant with tailor-made ground support products and an optimized supply chain

In 2012, work started at one of the largest private construction contracts in South America: The Alto Maipo Hydroelectric Power Plant in the Maipo Valley south-east of Santiago de Chile. The project with a total capacity of approximately 531MW includes the two power stations Alfalfal II and Las Lajas as well as several tunnels and shafts with a total length of 70km.

The tunnels and shafts are being excavated using the New Austrian Tunneling Method (NATM) as well as Tunnel Boring Machines (TBMs).

Since the start of construction work in 2012, DSI Underground Chile contributed to this major project by supplying a comprehensive range of ground support products including friction stabilizers, forepoling boards, lattice girders, AT – Pipe Umbrella Systems and DYWI® Drill Hollow Bar Anchors.

Within the scope of a current order, DSI Underground Chile also supplied GEWI® Anchors, friction bolts, cable bolts, Fast Anchors (combination bolts), OMEGA-BOLT® Expandable Friction Bolts, resin and threadbars for the efficient advancement of the tunnels and shafts. Up to 75% (51 km) could already be completed by 2019.

As the exclusive supplier of ground support products for the project, DSI Underground Chile provided all products and systems to the jobsite just-in-time and optimized the supply chain for ground support products in close cooperation with the customer STRABAG. The General Contractor was very satisfied with the fast reaction times, the know-how and the tailor-made products of DSI Underground.

Teck restructures sales book to target more China sales

Coking coal major Teck Resources has announced that it is restructuring its sales book for next year to target higher sales to China, where prices have increased on the back of rising demand.

The Canadian major is targeting Chinese sales of 7.5 million tonnes in 2021, which it aims to sell at CFR China pricing that is currently at a premium of about $50/t to Australian FOB spot pricing.

Teck explained recently that pricing in China for its steelmaking coal had started to increase in the middle of the current quarter, when a large portion of its overall sales were already concluded. However, additional spot sales to China were concluded gradually and the miner had achieved an average premium of more than $35/t above Australian FOB spot pricing at the time each sale was concluded.

The most recent three cargos were sold at prices between $160/t and $165/t CFR China, it said in a statement.

While estimated fourth quarter sales remained within Teck's existing guidance of 5.8-million tonnes to 6.2-million tonnes, the company said 20% of these sales were now to Chinese customers.

"In a declining coal price environment, our realised coal price relative to benchmark would normally be lower than the long-term average of 92%. As a result of these recent sales at premium prices, however, we are estimating that our fourth quarter realised price will reflect that long term average of approximately 92% despite the price drop for markets outside China where the majority of Teck's steelmaking coal is sold," it said in a statement.

Workers at Lundin's Candelaria mine accept new agreement

One of the unions on strike at Chile's Candelaria copper mine accepted a 30-month collective agreement from Lundin Mining , the company and the union said recently.

The Candelaria AOS Union, representing about 550 workers at Lundin's Candelaria operations in Chile, accepted the last formal offer, presented by Candelaria on 12 November, the company said.it was assessing a resumption of partial operations at the mine, while the other union, Candelaria Mine Workers Union, representing about 350 workers, continues its strike.

The proposal includes increases in allocations and payments for closing the negotiations of 17.5 million pesos ($22 800).

Evelyn Walter, president of the union, stated that a promise by the company to review aspects not touched in the latest round had been the "most important" part of the agreement..

"The pay deal was for $17.5 million gross, so taxes will have to be deducted from that, and there was also decent agreement on benefits," he said in a message.

The Candelaria copper mine, owned by the Canadian miner, announced plans to suspend operations at the mine on 20 October, after the two unions called on their workers to begin strikes.

Orica and Epiroc unveil prototype system for first stages of underground automation

Orica and Epiroc Rock Drills AB have successfully co-developed a prototype of the world's first semi-automated explosives delivery system.

Customers in the underground mining industry can look forward to safer, efficient and more productive development blasting as early as the end of 2021, as Orica and Epiroc commence commissioning on Avatel™, the first-of-its-kind, industry-driven explosives delivery system in coming weeks.

A sought-after technology by customers in the underground hard rock mining sector, Avatel™ will deliver a completely new way of approaching development blasting operations by eliminating charge crew exposure at the face.

The solution provides safe access for an operator in cab to execute the development cycle while reducing the reliance on costly, time-consuming and at-times ineffective controls put in place to manage the risks to personnel working in one of the highest risk areas of an underground mine.

Orica's Chief Commercial and Technology Officer Angus Melbourne said: "The mining industry is moving rapidly toward a digitally integrated and automated future, and Avatel will fulfil our shared vision of developing safer and more productive blasting solutions.

"Achieving this significant development milestone, despite COVID-19 disruptions, shows the strength of our collaboration with Epiroc and our collective ability to deliver the future of mining."

Epiroc's President Underground division Sami Niiranen said: "With this partnership, we continue to raise the safety bar by combining world leading technologies that will make a difference in underground mines.

"The Avatel prototype represents the first step towards autonomous charging – a vital step in the journey toward safer and more productive blasting operations underground. We are looking forward to bringing this ground-breaking solution to customers worldwide."

A key enabling technology of Avatel™ and Orica's automation vision is WebGen™, the world's first fully wireless initiation system. When combined with Orica's LOADPlus™ smart control system, specifically designed onboard storage, assembly, digital encoding capability and Subtek™ Control bulk emulsion, Avatel™ provides customers with complete and repeatable control over blast energy from design through to execution.

Built on the foundation of Epiroc's proven Boomer M2 carrier, and integrated with Orica's latest explosives technology, Avatel™ is a twin boom, semi-autonomous and fully mechanized development charging solution that allows a single operator to complete the entire charging cycle from the safety of Epiroc's enclosed Roll-Over Protection Structure (ROPS) and Falling Object Protective Structure (FOPS) certified cabin.

Avatel™ is equipped with the most sophisticated version of Epiroc's acclaimed Rig Control System (version 5). Through its intuitive interface, with a large touchscreen and dual multifunctional joysticks, and combined with Epiroc´s computer assisted boom positioning features, it can be easily handled. Integrated with Orica's LOADPlus™, charge plans and other important data will be communicated between the systems.

The advanced and robust feed design of Avatel™ builds on Epiroc's solid application design experience, further adapted to match conditions this new solution will face. Future developments can be extended to other Epiroc carriers including battery driveline. Other key advantages include flexibility at the face through Epiroc´s dual diesel/electric plug-in power solution.

The convergence of these technologies ultimately ensures that the right explosives will be safely delivered into the right holes and given the right timing to achieve optimal efficiencies and the desired outcomes.

Extensive trials of Avatel™ will take place throughout 2021, before the first commercially available systems are expected to enter service.

Orica announced in November 2019 that it had entered a partnership with Epiroc to develop a semi-automated explosives delivery system.

Keestrack exploring Russia and South-East Europe

By hiring Florin Ioia as Area Sales Manager for Russia and South-East Europe Keestrack enforced its sales team and is trying to expand and professionalize its support to their dealer network.

With over 16 years of experience within the construction equipment industry on an international level Florin brings knowledge and professionalism into these markets. He has a track-record of working at important players in the construction industry like: Bergerat Monnoyer (Caterpillar dealer), Powerscreen, Terex washing systems and Portafill.

At Keestrack Florin Ioia will be responsible for the following territories: Romania, Croatia, Bulgaria, Russia, Serbia, Bosnia Herzegovina, Montenegro, Macedonia & Ukraine, managing and acquiring dealers for Keestrack Mobile Crushing and Screening Equipment.

Positive future

Florin sees a positive future for his territory. “Even though we live in some troubled times right now, infrastructure for travelling and logistics will still be essential. And considering that 1 km of highway needs around 25.000 tons of aggregates, I predict a great future for the crushing and screening equipment industry. Add to this the 400 tons of aggregates used for building an average home, and being part of this industry looks like a great idea when choosing a career”, according to Florin.

“Eastern Europe is an area with great potential as the need for natural, manufactured and recycled aggregates will be at a high level for many years to come in order to come to the same economic development as in West-Europe. If you consider the fact that in a country like The Netherlands, with a territory of 40.000 km², it has 2.800 km of highways, while Bulgaria, with a territory of 110.000 km², has 800 km of highways. Recovering this gap means a lot of aggregates, so a significant demand for crushing and screening equipment,” Florin continues.

Advantages

The advantages of Tracked mobile equipment according Florin are the following: “The versatility of mobile equipment is always an advantage compared to static plants due to less logistic costs. But one of the big advantages of a static plant was it could be an electric driven system, with a significant lower production cost. With the development of electrical driven system in the mobile plants industry, things have changed a lot. A mobile e-drive plant could be pure gold for a quarry, combining the versatility and a lower operational cost. And this is where Keestrack is a game changer in the industry. As there are many contractors involved in national projects of infrastructure, moving their equipment from on site to another on the route of a new highway, the e-driven equipment from Keestrack would definitely be the first choice for many of them.”

Strengths

“One of the main strengths of Keestrack is its ability for innovation according to the needs of its customers. The e-driven system (the ability to run a plant in Diesel/electric mode or electrical plug-in mode) is one of the best examples” in fact this is exactly the reason Florin wanted to start working at Keestrack as he sees Keestrack being the promoter of innovation in the crushing and screening industry, while having a good understanding of how the industry will develop in future.

The fact it is still an independent company, with its founders still involved in the business and in direct contact with the company team members and distribution partners, made him decide it is a great place to work as any communication will definitely reach the right person, so you are not missing any business opportunity. This also applies to the distribution network: as a Keestrack distribution partner, you have a close human relationship and direct contact with the founders, so it is not just a B2B relation, but it goes further than that, which makes a partner to feel he is part of the family.

“Also the product range and the various options which can be equipped on a plant, providing the user the optimum configuration for his application to help him reach the standards of the aggregates and recycling industry, is another example of the strength of the Keestrack brand”, according to Florin.

Considering this two strengths above, we can say Keestrack is well prepared to tackle one of the best long-term opportunities in the area: in countries like Romania, Croatia, Bulgaria, which are part of the European Union, the European Green Deal (a climate neutral economy by 2050) suits perfectly the electrical driven system in which Keestrack invests huge efforts.

In a territory like Russia, there is still a great coal industry, which is looking for high productivity equipment, especially impactors. This is a brilliant opportunity as Keestrack has the R6 model, which suits perfectly the demands of the industry. Keestrack already sold several R6, which are reaching a productivity of almost 700 tph in coal applications.

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The world relies on mining for raw materials to drive human progress. And mining companies rely on us to drive their progress underground. By reinforcing their mines, safeguarding their people and protecting their investment, we help keep their mines open to supply precious metals and minerals to help the world advance.

We reinforce progress – for our customers, and for the world.

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Rinehart urges government to cut red tape

Gina Rinehart.

Iron ore mining magnate Gina Rinehart has urged the Australian Government to stop holding back industry growth and to cut green and red tapes to facilitate future investment.

Rinehart addressed Australia's leaders during the National Mining and Related Industries Day's Mates for Mining morning tea, reflecting on mining's significant contribution to the nation's economy.

However, she advised that the industry cannot sit on its laurels, stating that the day is a time to remind the nation that the industry is necessary to maintain living standards of all Australians.

"Please don't forget it was only a few years ago that our industry was faced with both mineral resource rent and carbon tax, a double whammy which would have deprived our industry of the profits needed for investment and for extending our mines and/or building new mines, indeed would have devastated many in the industry," Rinehart said.

Despite these challenges, Rinehart has led Roy Hill Holdings majority owner Hancock Prospecting to $4.1 billion in net profit after tax during the 2020 financial year, representing a 50% plus increase to bottom line profitability.

Hancock has also drilled 95,000 metres at the Mulga Downs project, expanding the iron ore resource by 290 million tonnes, securing the company's future success in producing and exporting Western Australian iron ore.

To secure this growth opportunity, Rinehart said it is necessary for the Australian Government to make the difficult decisions to cut costs and tape to increase investor appeal.

"We cannot look to our government to ensure the future of the industry. The government might mention the word investment but fail year after year to take hard decisions to cutting taxes, to make Australia, our very high-cost country more appealing for investments," she said.

"Never lose an opportunity to encourage the government to make the tough decisions and certainly never let the government think it can buy our votes with any form of hand outs, i.e., our tax dollars. We want them to act more responsibly in our industry's best interests.

"Living in constantly changing times, the best protection for the industry is the ability to be flexible and not be constrained by tape, keeping costs down so we can be internationally cost competitive despite natural challenges."

Rinehart also acknowledged the hard work of the Australian mining industry, in particular Hancock's fly-in, fly-out workers, who made personal sacrifices to support their company and industry during the coronavirus pandemic.

Tata Steel tests coking coal samples from Russia for producing steel

Tata Steel has tested coking coal samples from Russia for making steel through the blast furnace route, its Managing Director and Chief Executive Officer T V Narendran said.

The development assumes significance in the domestic steel industry as a fruitful result of the experiment would break the monopoly of Australia in coking coal supply to India.

According to official data, the country imports about 56 million tonnes (MT) of coking coal worth around Rs 72,000 crore. Out of this, about 45 MT is imported from the continent nation alone.

"We have imported some coking coal from Russia. The east coast of Russia is a good source," Narendran said.

The CEO said this while replying to a question related to the company's contribution to the steel ministry's ongoing efforts to reduce India's dependence on select countries for sourcing of coking coal.

Earlier, the ministry asked the steel makers to get in coking coal from Russia and test the raw material at their plants and update on the result of the same.

Coking coal is a key raw material used for making steel using the blast furnace route, besides iron ore.

"We support the government's initiative to look at Russia as a source (of coking coal). It is a good option for us to have, otherwise we are overdependent on Australia," he said.

He added that Australia also often has cyclone and weather issues. "For many reasons, it is good for us to have more than one option. We have explored and tried out some material."

Tata Steel produces steel using its blast furnace at its 11-MTPA (million tonnes per annum) plant at Jamshedpur in Jharkhand and 3-MTPA plant at Kalinganagar in Odisha.

When Tata Steel were contacted for details (with reference to the experiment), a company spokesperson said, "There is no information available at the moment related to it."

Earlier, Steel Authority of India Ltd (SAIL) Chairman A K Chaudhary also informed about similar initiatives being undertaken by the state-owned steel maker.

In an interview he had said the domestic steelmakers depend heavily on imported coking coal.

The company is looking at new destinations and vendors for sourcing coking coal from the international market to avoid dependence on limited sources, Chaudhary said.

Besides Australia, part of coking coal demand is also met from South Africa, Canada and the US.

Flender presents the new double-cardanic N-Eupex DK and increases the performance of the N-Eupex series

Flender introduces a new type in the N-Eupex coupling series, while increasing the performance and bore capacity of the entire series. The new double-cardanic N-Eupex DK connects the shaft ends of the drive and driven machine via two elastomer joints instead of only one joint, as is the case with the other types. The introduction of the second elastomer joint increases the damping properties of the coupling and results in a lower torsional stiffness. This reduces vibrations, and the adjacent machine components are less stressed. In addition, the possible radial offset is increased more than fourfold. The restoring forces are thus reduced by more than half depending on size, offset and installation dimension. The encapsulation of the elastomers ensures a constructive catch protection of the intermediate sleeve.

The N-Eupex DK adds a double-cardanic variant to the already existing short and long construction types. It is universally applicable, but it is particularly suitable for pump applications.

With the introduction of the double-cardanic design, the selection of N-Eupex couplings can be adjusted even more specifically to the respective application.

At the same time, Flender achieved to increase the performance of the entire N-Eupex series by approximately 30%, and the bore capacity by up to 25%. The increased power density was achieved through extensive testing and material optimization. As a result, users benefit from higher torque, increased rotation speed and a change in size. The same performance can now be achieved with a smaller size.

With the so-called G-hub, the N-Eupex DK also receives a new, split hub design. The two half shells of the hub are bolted together. When the clamping screws are tightened, the half-shells center themselves over the feather key and position themselves correctly relative to each other. The feather key connection is therefore free of play. In addition, the service friendliness is increased. The

coupled driving and driven machines do not have to be moved during assembly or disassembly of the coupling. This halves the time required compared to conventional hub design.

The N-Eupex DK is available in ten sizes for torques from 48 Nm to 2,300 Nm. The bore capacity of the hubs is suitable for shaft ends with diameters between 20 and 150 mm. The permissible speed for small diameters is 5,500 rpm, for large diameters 3,000 rpm. The N-Eupex DK can be used at ambient temperatures from -30 degrees Celsius to +80 degrees Celsius. It is ATEX certified and therefore suitable for use in potentially explosive atmospheres.

A TEC will install Flash Dryer for alternative fuels at LafargeHolcim Mannersdorf

To reduce the moisture content of the alternative fuel (RDF) for the kiln burner, LafargeHolcim Mannersdorf awarded A TEC a contract for the implementation of it's innovative Flash Dryer. A TEC has already been nominated earlier with the engineering and supply of key equipment separately and now for the supply of all structural steel, residual ductwork and the mechanical erection works.

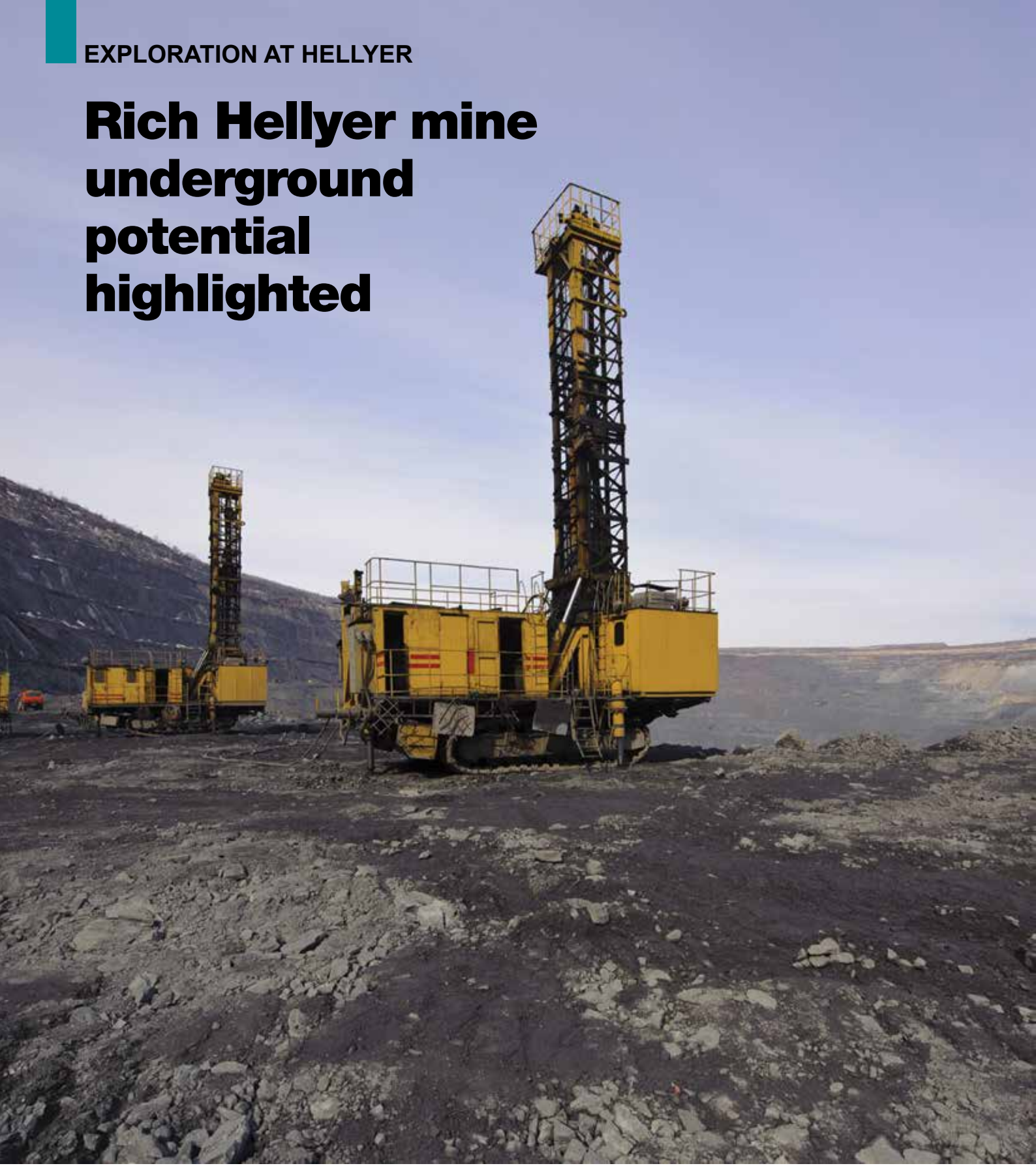
The project will be realized by the end of quarter one, 2021.

LafargeHolcim Mannersdorf is one of the leading manufacturers of high quality cement in Austria. The plant in Mannersdorf has the highest clinker production of all plants in Austria.

Flash Dryer for alternative fuels:

Reaching high thermal substitution rates (TSR) requires firing of alternative fuels at the kiln burner. To reach a stable sintering zone for the required clinker quality a high fuel quality (high LCV, small particle size) is needed, otherwise the clinker quality suffers or the TSR is limited. With the A TEC Flash Dryer various waste heat sources can be used (clinker cooler flue gas, bypass gas, preheater gas, etc.). The material is dosed to the hot gas flow in the flash dryer and transported with this gas flow, while the moisture is evaporated, to a cyclone and a subsequent filter where the fuel is separated from the gas flow and on-line fed to a kiln burner or a satellite burner. In addition to the drying the lifting effect of the gas can separate 3D impurities which contributes in a further increase of the fuel quality.

Rich Hellyer mine underground potential highlighted



Exploration to resume for high-grade base metal-gold deposits at Hellyer Mine after 10-year hiatus

NQ Minerals Plc announces that it plans to break a 10-year hiatus in exploration work at its highly prospective Hellyer Project, located in the Mt Read Volcanic Belt; a geological terrain in NW Tasmanian renowned for large scale and high-grade polymetallic (copper-lead-zinc-silver-gold) deposits.

The Hellyer deposit was a large scale, very high-grade lead-zinc mine. Past production under Aberfoyle (1986 – 2000)

totalled 16.5 million tonnes at 13.9% zinc, 7.2% lead, 0.4% copper, 167 g/t silver and 2.5 g/t gold and under Bass Metals (2010-2012) totalled 0.5 million tonnes at 7.8% zinc, 4.2% lead, 0.3% copper, 101 g/t silver and 1.7 g/t gold from the Fossey Mine. There has been no exploration work undertaken on the Hellyer Mine Lease since underground mining operations ceased in mid-2012.

NQ is currently producing lead and zinc concentrates (with significant gold and silver credits) by reclaiming the Hellyer Mine tailings generated from the former mining operations and processing through the Hellyer concentrator plant at the rate of over 1.2 million tonnes per annum.

Since acquiring the exclusive rights to the underground resources at Hellyer from Bass Metals Ltd on 7 January 2020, NQ has commenced interrogating a high-quality data set acquired from Bass. It is clear that work essentially ceased 'mid-stream' in early 2012 and left several significant 'open' targets' at a time when Bass was at the cusp of gaining a greater understanding of the key ore-deposit indicators. This follows their discovery of the Fossey deposit only 150 metres south of the large-scale Hellyer deposit, but in the footwall zone, below the classic 'Hellyer ore position', where the majority of exploration was targeted for the previous 30 years.

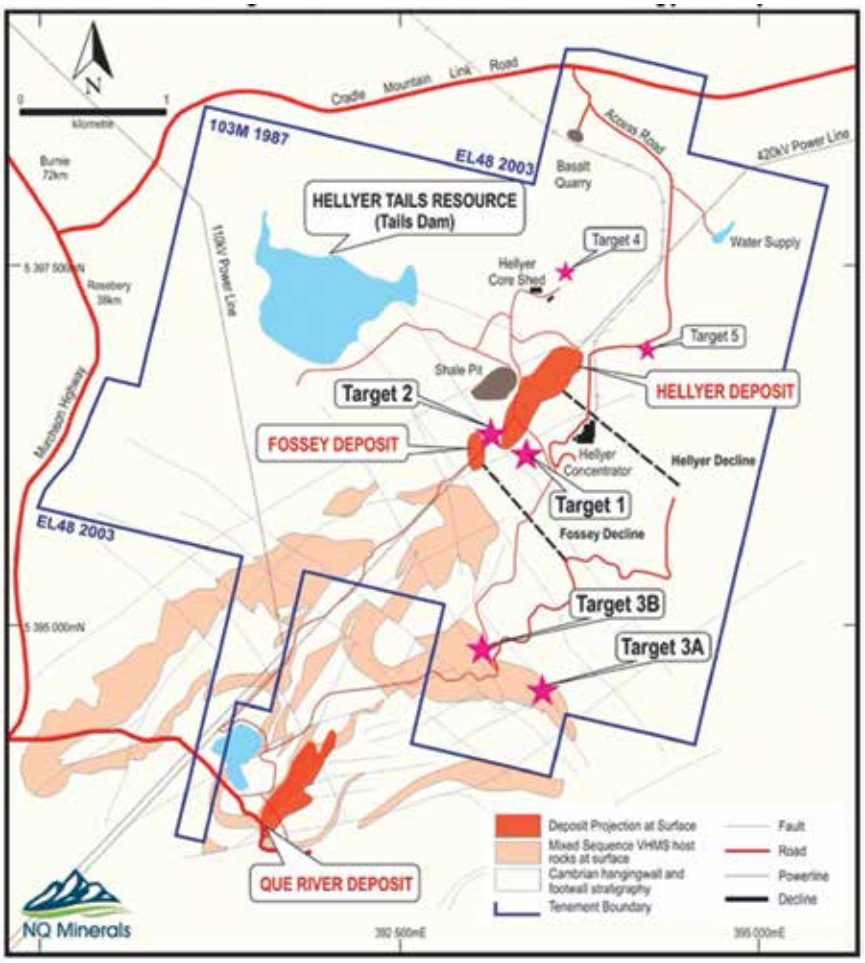


Figure 1: Modelled DHEM Target Locations and Schematic Geology – Hellyer Mine Lease

Ten years later, with the benefit of significantly more advanced exploration tools, specifically more powerful geophysical techniques, NQ has commenced a systematic review of these targets, focused initially on 'prioirty-1' areas, namely in close proximity to the known deposits and existing mine infrastructure.

NQ Minerals' Executive Chairman, Mr David Lenigas, said;

"There is now significant potential to define new and extensive high-grade mineralisation at Hellyer, one of the world's great polymetallic high-grade mines. We are operating in one of the mostly highly mineralised geological terrains in the world and we have a golden opportunity to continue Bass's work from 2012 to build-up the existing significant underground resource inventory and extend the Hellyer mine life to underpin this operation for a very long time. The tailings reprocessing Phase 1, now running at over 1.2 million tonnes per year, has another 8 years to run with its current lead/zinc strategy and will generate significant cash flow for the Company, but it's a finite resource. Stage 2 of the current operations will focus on recovering the significant gold and silver inventory in the tailings, but metallurgical test work continues with respect to this next phase of tailings reprocessing. To move Hellyer back into underground mining is a logical and natural progression, especially considering we have the Hellyer plant fully operational."

Mineralisation on the Hellyer Mine Lease comprises massive base metal sulphide lenses within the core of a broadly folded volcanic-sedimentary sequence which plunges to the north-northeast. As the mineralisation generally does not outcrop, geophysics has played a vital part in mineral discoveries in the Hellyer region and down-hole electromagnetics (DHEM) is a core technique. NQ has now completed a first pass review of historical DHEM data for 8 surveyed drill holes in the priority-1 area. Remodelling work of the DHEM undertaken by Southern Geoscience, with input from former Hellyer geologists, has highlighted the significant enhancement in modelling software, and has identified four high priority targets/zones (Target 1 to 3B), which warrant follow-up exploration work, as presented in **Figure 1**, and represent significant potential for further base metals discoveries.

GEOPHYSICAL MODELLING OUTCOMES

The four high priority target zones to be followed up were identified in areas of known mineralisation and or significant alteration near the prospective 'ore-forming' stratigraphic horizon adjacent to the Hellyer underground mine envelope.

The modelled targets comprise 'plates' representing modelled conductive bodies, potentially massive base metal sulphide lenses. Due to constraints imposed by the data from historical surveys, the modelled plates are not well 'constrained' in terms of 3-D spatial co-ordinates, which is essential for efficient follow up drill testing. A

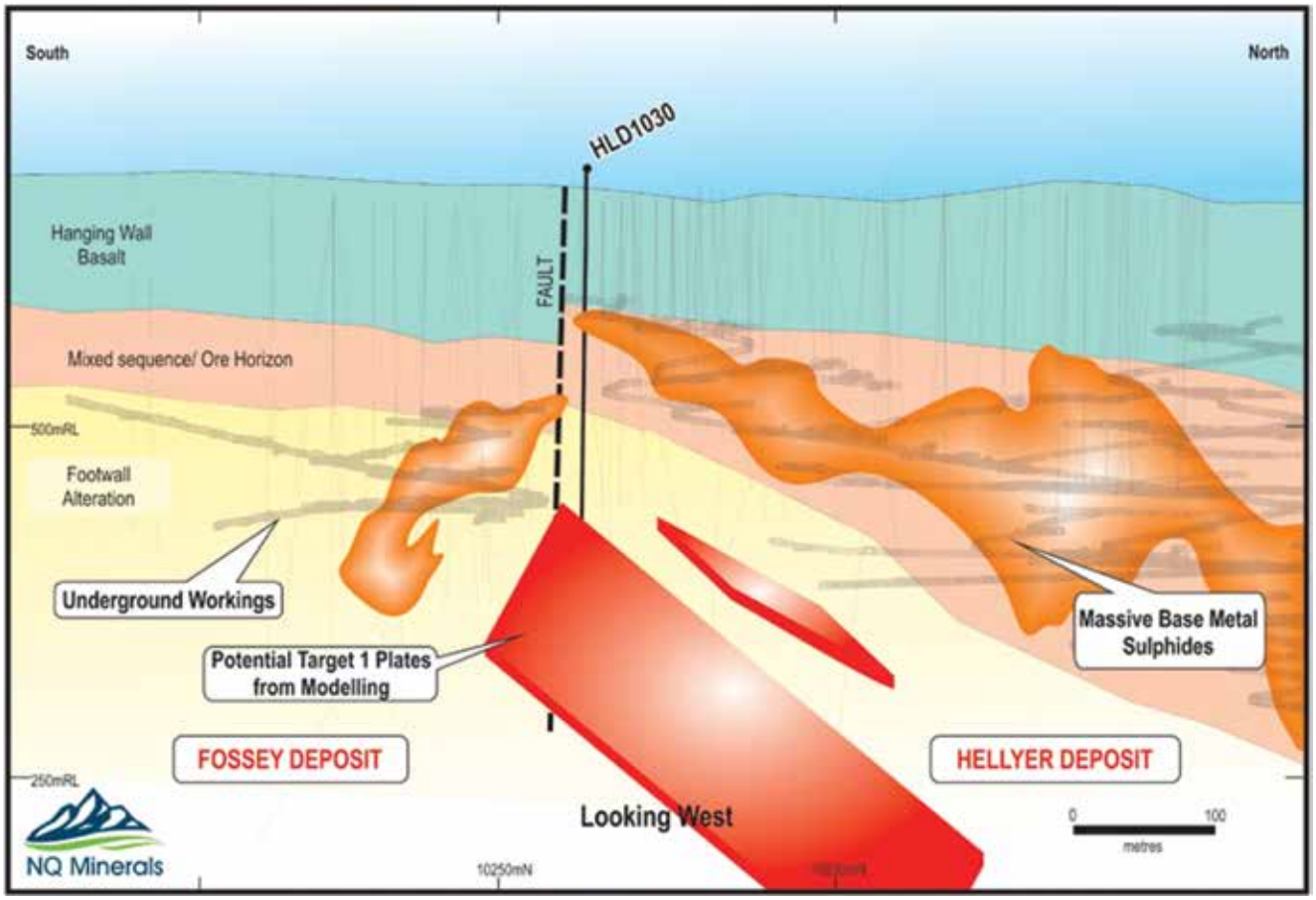


Figure 2: Schematic long section – looking west with modelled – 1 plates illustrated.

number of potential model scenarios are presented, and spatial/geometry variance is currently high without further modern, high powered DHEM surveying efforts and re-modelling.

The following notes provide a summary overview of the high priority targets modelled:

- **Target 1** is associated with an extensive zone of alteration which hosts the McKay Prospect discovered in July 2011 – 7 metres at 22.3% Zn, 9.9% Pb, 0.7% Cu, 181 g/t Ag and 3.4 g/t Au. This intercept was in HLD 1030, which is the drill hole utilised for the DHEM which generated the modelled target-plates illustrated in **Figure 2**, as well as an 'in-hole' conductor representing the mineralisation intersected. Follow-up drilling at the time around this intercept failed to significantly extend this very high-grade massive base metal sulphide lens but did extend the zone of prospective alteration. The modelled plates, within the extensive alteration zone, highlight the potential for a significant mineralised body associated with this McKay zone mineralisation (Refer **Figure 2**).

- **Target 2** is a high priority target located immediately southwest of the Hellyer deposit. The modelled plates based on DHEM survey of HLD975, occur within prospective stratigraphy with anomalous geochemistry and strong alteration – in close proximity to both the Fossey and Hellyer mine development (Refer **Figure 3**).

- **Targets 3A and 3B** both occur within the historical Switchback Prospect where a large-scale alteration system and several mineralised intercepts were recorded. This area has also yielded highly encouraging trace element and isotope data indicating the presence of volcanogenic massive sulphide (VMS) mineralisation. Due to structural complexities, the original source for high-grade VMS clasts intersected previously such as in HED012 (4.85 metres at 1.6% Zn, 1.2% Pb, 18 g/t Ag and 0.9 g/t Au) has never been found; if preserved this represents an exciting base metal sulphide target.

- **Targets 4** is a lower priority target zone occurring in the interpreted hanging wall to the main Hellyer 'ore-position' at depth to the north of the Hellyer deposit.

- **Target 5** is also a lower priority target to the north of Hellyer – requiring additional interpretive work prior to any further assessment of this deep target zone.

NEXT STEPS

NQ is planning a major program to assess these preliminary modelled targets which is planned to include:

- Assessing the condition of each of the DHEM surveyed drill holes and possibly neighbouring holes to be able to re-enter and case with PVC to the required depth. The PVC casing is necessary to protect the DHEM probe which is lowered into the drill hole and costs ~$100,000 to replace if the hole collapses and it cannot be recovered.

- As required, clear the drill hole utilising a small drill rig and case with PVC pipe.

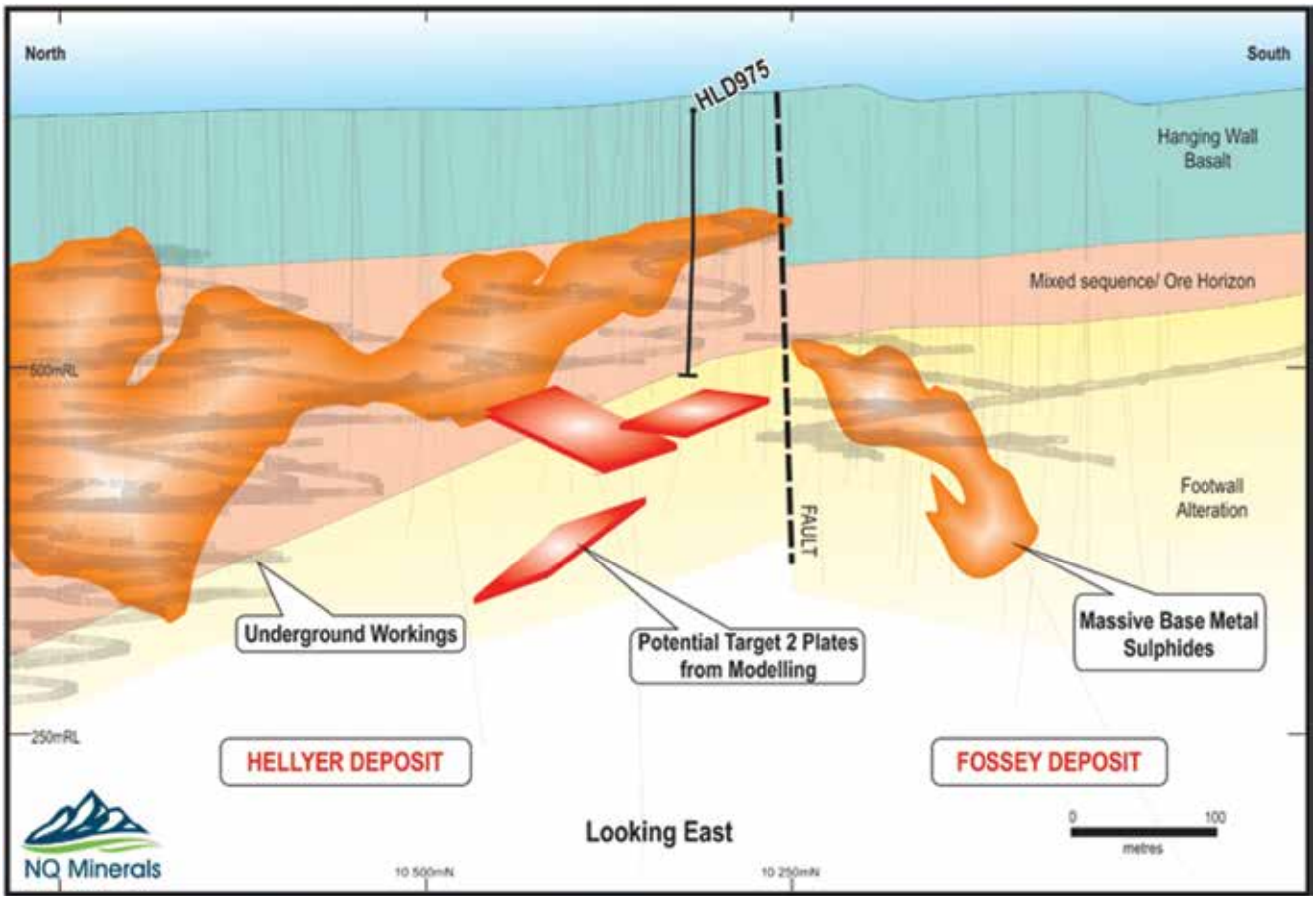


Figure 3: Schematic long section – looking east with modelled target 2 plates illustrated

- Resurvey and clear lines at surface to enable wire loop arrays (several kilometres in length) to be laid out on the ground as part of the new DHEM survey – for each target zone.

- Mobilise geophysical contractor to Hellyer to undertake the DHEM surveys.

There have been significant enhancements to DHEM equipment since the last DHEM surveys were run at Hellyer approximately 10 years ago. This creates a new and very exciting opportunity for NQ to leverage off major technical advances to better resolve spatially any potential targets and execute better targeted follow-up drilling if warranted. This includes:

- Utilising much higher electrical power/current inputs to penetrate far deeper into the ground to detect any conductive bodies at greater distances from exploration drill holes;

- Optimised Electro-Magnetic ("EM") loop arrays to get better 3-D resolution of any conductive units identified – through varied coupling scenarios;

- Access to significantly enhanced modelling software to also resolve the position and dimensions of any modelled plates; and

- Working in the context of an updated geological target model which extends deeper below the traditional 'ore-horizon' such as hosts the new Fossey and McKay discoveries.

NQ plans to undertake this work program on site in the Australian Spring, possibly commencing October-November 2020, depending on rig and crew availability.

These technological advantages coupled with the important geological advances achieved by Bass, pre 2012, makes for a compelling exploration opportunity. There are further targets to follow-up, but those targets discussed were selected due to their proximity to existing mining and processing infrastructure leading to rapid development should they be proved up. Insights gained from these first four targets will be applied to other currently lower priority targets.

COMPETENT PERSON'S STATEMENT (NQ MINERALS PLC)

The information in this report that relates to the Hellyer project is based on information compiled by Mr. Roger Jackson, an Executive Director of the Company, who is a 25+ year Member of the Australasian Institute of Mining and Metallurgy (MAusIMM) and a Member of Australian Institute of Company Directors. Mr. Jackson has sufficient experience which is relevant to the style of mineralisation and type of deposits under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the 2012 Edition of the "Australasian Code for Reporting of Exploration results, Mineral Resources and Ore Reserves". Mr. Jackson consents to the inclusion of the data contained in relevant resource reports used for this announcement as well as the matters, form and context in which the relevant data appears.

Indian underground developments

Despite its growth, the contribution of India's mining industry to GDP has remained relatively stable since 1970. At present the nation is a leading world producer of 11 major mineral and energy commodities, including bauxite, chromite, coal, iron ore and manganese. Recent economic reforms have stimulated industrial expansion in India; however, problems, including a restricted private sector role in resource development and ineffective government mineral strategies in the past limited future growth although . recent changes in the Indian Government's approach to mining has now opened up opportunities for private sector involvement in the industry, including international METS firms.

India's mining sector is vast. With 1,531 mines in operation, the country produces 95 minerals including 4 that are fuel-related, 10 metallic, 23 non-metallic, 3 atomic and 55 minor minerals. India is the world's second largest crude steel producer, with an output of 106.5 MT in 2018. India's steel consumption has grown by 7.5% per year over the last two years, outpacing the global growth rate of 5%.

COAL

India is also the second largest producer of coal globally, with a compound annual growth rate (CAGR) of 4.6% from 2014-2019 taking output to 730.35 MT. Coal's share of India's primary energy consumption is expected to be 48% by 2040. To date, more than 40 mines with an annual production capacity in excess of 500 million tonnes of coal have been allocated to state and federal government entities via competitive bidding. These entities will be inviting bids for coal mining in the near future. The preferred model for engagement is a Mine Development and Operations (MDO) model. Over the decades, the value of mineral production has also risen and, as of 2015-16, stood at around Rs. 2.82 trillion. There are over 3,500 mining leases that are in force in the country across 23 states covering an area of 316,290.55 hectares. Of those, nearly 70% are in five states alone – Madhya Pradesh (702 mining leases), Tamil Nadu (464), Andhra Pradesh (453), Gujarat (432), and Karnataka (376).

The mine development and operations (MDO) model is a variant of the BOT (Build, Operate and Transfer) model. Its purpose is to combine the efficiencies and expertise of private mining contractors with public sector ownership or lessees. Contracts tend to operate such that mining companies supply coal or minerals to the mine owners in return for service fees charged on a per tonne basis. Risks are shared. The attractions of the MDO model are that it provides fresh opportunities for mining companies, while maximising returns on investment for public bodies that own green field mine sites. MDO contracts tend to be long term. Successful operations require robust mine-design and engineering capabilities as well as the financial strength to sustain viable operations over the long haul. The upsides are substantial, however. With 15-25-year lifespans, the contracts generate reliable, long-term revenue streams, which strengthen contractors' order books. They also help EPC companies to diversify.

In June this year, Prime Minister Narendra Modi said India will turn the COVID-19 crisis into an opportunity and he hailed it is a major step in making the country self-reliant in the energy sector. However, the government's decision has not inspired much confidence in investors as they feel

auctions in times of a pandemic is a dampener. Instead, they sought extensions of the auctions by a few months.

THE SHIFT TO RENEWABLES

The government's launch of coal auctions for commercial coal mining once again triggered the debate around transition to clean energy. The shift to renewable energy from coal is one of the main pillars of a transition that is deemed to be fair to communities, protects health and environment and boosts growth. Moreover, it is also part of the global efforts to cut down on coal to control climate change. India has promised 175 GW of renewable power by 2022 and at least 350 GW by 2030. At present, India's overall installed renewable capacity is 87.66 GW and of installed solar power capacity is around 35 GW. However, the push and focus on renewables do not mean India is cutting down its focus on coal. According to CIL, in the next five years, it is going to open 55 new coal mines and expand at least 193 present ones. Together, these two steps will ensure an increase of 400 million tonnes in coal production. CIL has about 463 coal blocks with which the country can continue thermal power production for another 275 years.

REMOVING THE DISTINCTION BETWEEN CAPTIVE AND NON-CAPTIVE MINES

Another major amendment that the government intends to go ahead with is removing the distinction between captive and non-captive mines as it notes that captive mines are catering exclusively to their captive plants and the mining activity is restricted in terms of quantity and grade of mineral required by the captive plant.

This results in sub-optimal mining. It also creates an environmental hazard on account of heavy stock of unstable extracted minerals lying at the mine head that cannot be sold due to restriction in law. On the lines of commercial mining, all mineral blocks may also be auctioned for commercial mining without distinction of captive or merchant mines, noted the proposal while emphasising that the idea is to ensure that in future all mines will be auctioned without any end-use restriction.

The government also aims to remove the right of first refusal available to existing captive mines. According to the amendment proposal, the existing limit of allowing 25% of the total mineral excavated in the previous financial year, for which end-use was specified, is proposed to be increased to 50% for the auctioned captive mines beyond their specified captive use volumes.

S. Vijay Kumar, the former secretary of the ministry of mines, explained that the concept of "captive" and "non-captive" mining was not part of the mining law (except for coal), till the 2015 amendment that brought in "auctions" as the mode of grant of concessions.

"This distinction was regressive and contrary to global best practice, since it artificially segments the industry, and reduces the scope for the economy and resource-use efficiency. As such the removal of the distinction is a good step but should be taken to its logical conclusion (and not for only 50% of the production)," said Kumar.

IRON ORE

India's iron ore production is estimated to have risen by 14.2% in 2019, to reach 234.9Mt, owing to the acceleration in mine production for several non-captive mines – especially from merchant miners due to the expiration of leases in March this year. Production in 2020 is expected to decline to 205.7Mt; a delay in mineral auctions in Odisha, coupled with regulatory approvals, will be of major concern for Indian miners. Production over the forecast period is expected to grow at a CAGR of 7.2%, to reach 271.2Mt in 2024. This growth can be attributed to the commencement of new projects and the expansion of existing ones, such as the Kumaraswamy mine, the Daitari and Gandhamardhan mines and the Chiria iron ore mine.

The proposal seeks to remove the right of first refusal to existing holders of captive mines when these mines are put to auction in 2030. In the case of many iron mines, such as those currently held by Tata Steel, in case the auction is won by another bidder, the current steel making assets will be left stranded, while it will take the new owner time to restart the mine and reorient the transportation infrastructure to feed his steel plants. Large supply disruptions in the post-auction period, therefore, are possible, even likely. The alternative may be high and unsustainable bidding by the current owners, with every possibility of a winner's curse.

UNDERGROUND TECHNOLOGY

Highly mechanised underground mining technologies can meet the challenges of the Indian underground mining industry. But adoption of highly mechanised foreign technology is also not straightforward due to a variety of reasons. One of the major reasons is mining technology is generally site specific and required to modify as per the site conditions based on the geomining conditions of the mine. R&D support is a basic requirement to adopt any mining technology developed elsewhere, especially for underground mining. Automation in the underground mining industry is the need of the day. Introduction of integrated real time online information system for underground activities may transform the Indian underground mining industry. An appropriate and reliable remotely operated system is a vital requirement for designing, developing, or introducing

of advanced systems in underground mines for enhanced production, productivity, and safety. Development and application of robot and remote operation technologies will technologically empower Indian industries for efficient exploitation of underground seams. Indigenous R&D efforts are needed to overcome the problems of underground mining for sustainable underground extraction of coal and other minerals. Efforts are on at CSIR-Central Institute of Mining and Fuel Research (CSIR-CIMFR) to develop suitable underground mining methods indigenously as well as to evaluate suitability of foreign technologies, stepping in due to changing economic policy of the country.

CHALLENGERS

To streamline the process of extraction, choosing the right mining technology is a prerequisite. However, challenges pertaining to demand for high quality minerals, high land acquisition costs, and heavy dependence on hired equipment (without appropriate manpower for operations) create impediments to the introduction of appropriate technologies. Differentiating each technology and determining its efficiency enables a mining company to select the most suitable one.

Over the years, the demand for domestic output of high-quality expensive minerals has been increasing. Rocks rich in these minerals are buried deep within the hard earth crust and cannot be extracted using opencast mining techniques. In underground mining, the overlying rock is left in place and minerals are removed through shafts or tunnels. However, due to the high cost and safety issues involved in its implementation, there is a declining trend in underground mineral production. The demand for high quality coal for example can be met by adopting underground production methods such as cut-and-fill, bord-and-pillar, shrinkage stopping and longwall coal mining. These methods are supported by highly mechanised equipment. Key among these are continuous miners, longwall mining, load haul dumper and sub-level stoping.

The choice of the mining method is largely determined by factors such as depth, geology of the mineral deposit and the cost of equipment.

CONCLUSION- CONTINUOUS MINING ON THE RISE.

There is no other future option but to go for exploitation of deeper deposits by underground mining methods. Presently, the majority of underground mines in India are semi-mechanized using SDL/LHD with the chronical problem of very less productivity leading to huge loss per ton of production and the lack of capability of mass production by such technologies. It's high time to go for mass production from underground mining by adoption of suitable technologies Even though Longwall is quite successful in other countries, it had only limited success in India due to adverse strata conditions, lack of suitable locale for introduction of high capacity longwall mining, half-hearted approach to go for all out mechanization right from face to surface, and most importantly, depending on importing the technology without creating capabilities for absorption of the technology. Alternatively, application of a Continuous Miner may be the most potential technology of mass production suitable for Indian Geo-mining conditions due to its more flexibility in the operation, low capital requirement compared to Longwall, and the historical knowledge of bord and Pillar mining in India.

The new era of mechanized underground coal mining in India started with the implementation of Continuous Miner in 2002 .Since then there is a steady increase in Continuous Miners implemented in Indian coal mines from 1 to 16 with increasing mechanization and safety in underground mines. But still this is small number for 252 underground coal mines. Still Indian underground coal production is highly dependent on Semi-mechanized mining This is high time to adopt mechanized mining in majority of coal mines with Continuous Miner technology. Undoubtedly, the future of Indian underground mining lies in successful pillar extraction with Continuous Miners.

New Product Development – Retrac Type Reaming Bit

New Reaming Bit for Tunneling Drill and Blast

Reaming type bits in underground drilling and blasting operations are used to enlarge selected existing blast holes to bigger diameters for effective blasting and rock fragmentation. This is typically performed in tunneling, mining, and underground construction drilling operations. The larger reamed holes are not loaded with blasting agents and therefore allow the rock formation to implode during the explosion phase. The empty voids in these reamed holes promote better rock fragmentation and more efficient blasting patterns.

After blast holes are drilled in the tunnel face with hole diameters ranging from 43-51mm, certain holes in the pattern are enlarged with a typical reaming bit to 76-102mm, depending on the blast and rock formation requirements. Standard reaming bits feature face designs with dome or narrow nose fronts and are intended to effectively enlarge a predrilled hole. When they are retrieved out of the hole, however, at the end of the target hole depth, they often seize up due to the loose rock debris inside the hole formation.

"Our field support engineers recognized the need for better bit retrieval in face drilling operations.

After close collaboration with various drilling teams, our designers introduced the innovative retrac features in this new reaming bit," comments Pejman Eghdami, Executive Vice President.

Rockmore engineers addressed the challenge of retrieving these style bits by developing this new model that features retrac style cutting fins in the rear section to promote better retraction out of the hole. The fins effectively push out any rock chips trapped behind the bit when the drill string is pulled from the blast hole resulting in more efficient reaming operations in underground drilling operations.

The particular model shown is designed to ream from 41mm to 102mm holes and configured with a R32 thread connection to the tunneling rod.

Rockmore International is a global leader in the design and manufacturing of rock drilling tools since 1948.

WARMAN® Telescopic gland seal guards safeguard operators from rotating parts

The new patented guards make pump maintenance safer and can be retrofitted without pump disassembly.

Weir Minerals is proud to announce the global availability of new telescopic gland seal guards that further protect maintenance personnel performing gland seal adjustments on its industry-leading Warman® slurry pump range.

The guards never need to be removed in order to adjust the gland seal followers, making this routine task far safer. The telescopic design, which can be retrofitted into existing Warman® pumps without disassembly, ensures secure fitment no matter how the pump is set up.

"At Weir Minerals, we always put the safety of our customers and employees first. That's why I'm proud to announce these innovative gland seal guards, which provide miners with an elegant solution to a long-standing safety concern – how to safely adjust the gland seal of a slurry pump while it's operating," says Marcus Lane, Global Product Manager, Centrifugal Pumps.

"We need to adjust the glands whilst the pump is in operation. Historically this meant removing the guard and exposing personnel to rotating parts. The new guards never need to be removed during pump operation and address a number of safety concerns our service teams frequently observe on site, such as the possibility for the rotating elements to forcefully eject the tool being used to adjust the gland follower.

Another common concern is the tendency for operators to lay cloth over the seal area during adjustment to block the water spray. These fabrics can become entangled around the rotating shaft whilst also ensnaring the tool, fingers, hand or arm of the maintenance personnel," he continues.

"Warman telescopic gland seal guards fully protect maintenance personnel from potentially dangerous situations arising from an exposed shaft."

The guards, which comply with global standards including ISO 14120, ISO 13857, AS4024.1601 and AS4024.1801 are available for the majority of Warman® pumps including MCR, WBH and AH, and additional designs will be engineered upon request.

Manufactured from stainless steel to prevent corrosion, guards are painted golden yellow to be quickly identifiable as a safety feature.

Warman® telescopic gland seal guards are available worldwide.

The future of work in mining

What will jobs look like in intelligent mining operations?

Deloitte's Tracking the trends 2020 explores the action points

The COVID-19 crisis has exposed the siloed nature of mining companies and highlighted the need for integrated operations. This is likely to accelerate the adoption of digital technologies, artificial intelligence, and analytics in the mining industry. We examine what future mining jobs will be like in intelligent, integrated operations.

THE evolution of technology, from advanced data analytics to artificial intelligence (AI), has always had the potential to transform the mining industry by realizing operational efficiency improvements, enhancing productivity, improving safety performance, empowering employees to do more meaningful work and allowing communities to be more prosperous. Has today's crisis accelerated that trend?

In recent years, many mining companies have begun their digital journeys towards intelligent operations. Deloitte's *Tracking the trends 2020* report explored the following action points for mining companies to optimize their digital journeys and unlock sustainable value:

- Understand the amount of effort required to clean up data and upgrade technology infrastructure
- Integrate operations and governance by bringing planning and execution together in a closed loop system and integrating data across the entire value chain
- Understand the staffing and skill requirements in moving towards integrated operations centres (i.e., Nerve Centres)

The future of work in mining is not only about introducing new technologies but also about considering what role these technologies will play and what work will look like in a new organization that imbibes these new technologies. To help guide us in these uncharted territories, it is important to keep the end state in mind: "What outcomes drive value for the business?" These key business drivers can help tailor and redesign the organization to ensure that technology and organizational change empower this future organization, rather than debilitate it.

To achieve the desired value-driving outcomes, it is imperative to look out several years and understand and design for how humans could interact with the technology and with each other. Companies that have had successful digital journeys so far have often placed significant emphasis on change management to shift people's behaviour and engage with their work in new ways. Mining companies looking to capitalize on these trends will need to consider the future of work as they move towards integrated operations centres (i.e., Nerve Centres) that help guide decision-making across the value chain and reduce siloed behaviour's. They should consider

what skills and roles are needed to support the Nerve Centers in achieving the desired business outcomes, and whether they will build these capabilities in-house or outsource it to external partners. These organizations will need to consider the desired culture of the teams, defining what success looks like when the culture is in its desired state. The operations culture plan should be developed in line with the objectives that the organization is looking to achieve through its digital goals and vision.

To support the teams when using digital tools, it is important that principles for decision rights, escalation protocols, and role accountabilities are clearly identified. A transparent and clear understanding as to how each role contributes to the success of the organization provides the best opportunity for teams to tap into the many resources available and the collective situational awareness that this collaborative environment brings.

THE TIME FOR CHANGE IS NOW

Recently, the global pandemic resulting from the novel COVID-19 virus has seen organizations around the globe change how and where work gets done in an effort to curb the spread of the virus. Energy, resources, and industrial companies are among those facing the biggest constraints in offering flexible working and remote solutions. Some operations have, however, rapidly executed secondary control rooms, equipped with the relevant hardware and network capabilities to allow seamless handover between shifts in two separate locations. Some others have executed working-from-home capabilities by creating “dispatch packs” containing laptops and communication tools, enabling workers to operate and maintain control of on-site activities from the safety of their homes. For those performing essential services and therefore unable to work remotely, operations have focused on providing epidemic protection – ensuring sanitation, personal protective equipment, and safety of the workplace environment. Some others – for instance, those working on-site to support power utilities – have halved their operational efficiency to instill social distancing and other health-related measures. Meanwhile, those who have been unable to effectively mitigate the risk have had to shut down during this time.

Nobody knows exactly what the impact of these operational lockdowns will be on the industry, but many are realizing that there is a critical, accelerated need to fundamentally rethink how value is generated and redesign how work gets done. We are now seeing some clients actively revisit technologies such as tele-remote systems, autonomous vehicles, and automation of key areas of their operation. While many of these require significant capital investment at a time when commodity prices have been hit hard, they are weighing this up against the increased flexibility and performance improvement this offers in the midst of a crisis.

Now, more than ever before, an integrated operations center has become critical for any mining organization to provide an integrated single source of the truth built on real-time tracking of operational data across the value chain, enhance decision-making through advanced analytics, enable remote management of resources where feasible, and optimize workforce allocation and utilization, among others.

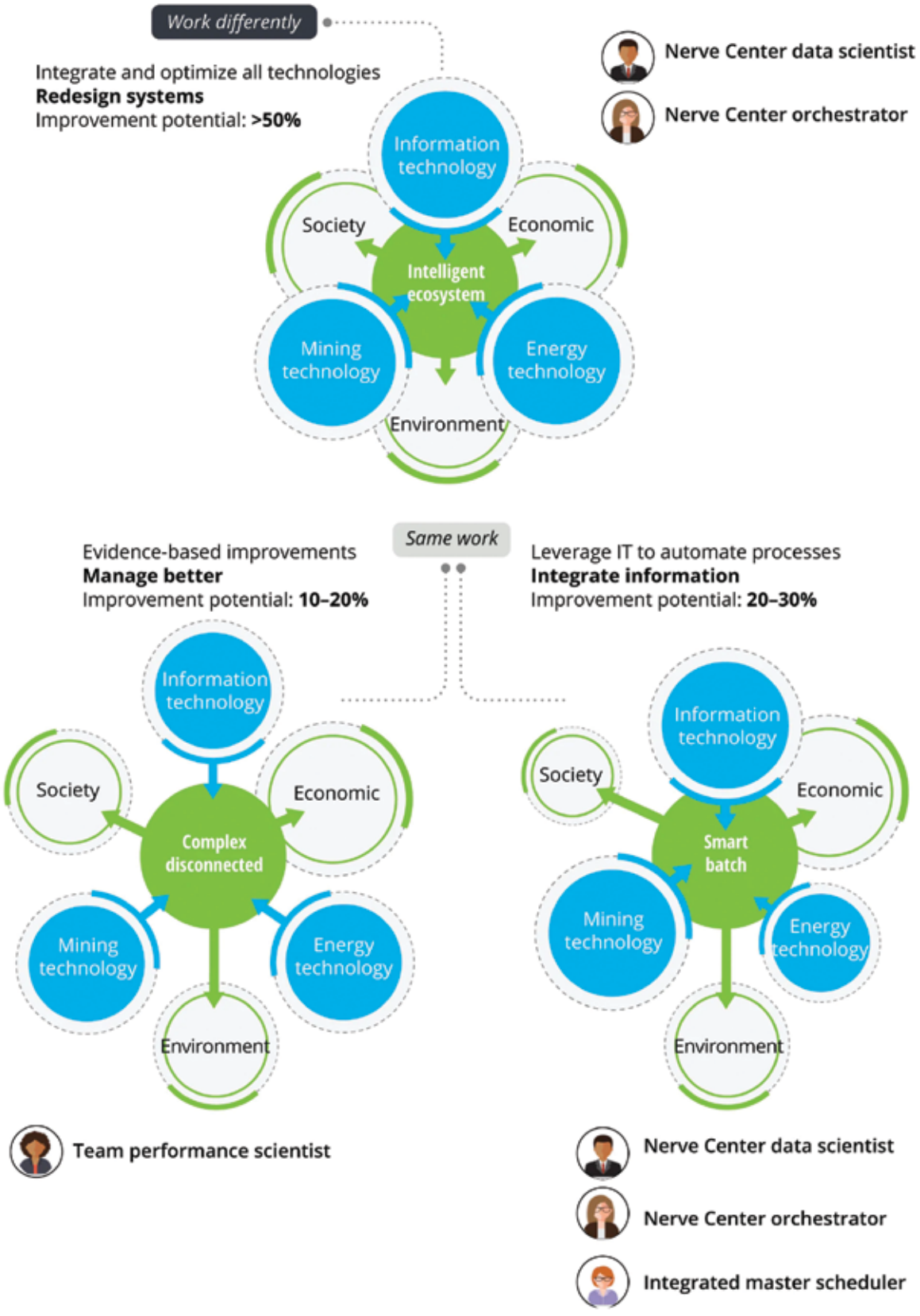
To help mining clients prepare for this new normal, we have developed personas for roles we deem important in unlocking the value of intelligent mining (**Figure 1**), enabled through Nerve Centers:

- Nerve Centre orchestrator
- Nerve Centre data scientist
- Integrated master scheduler
- Team performance scientist

Andrew Swart-Canada

Janine Nel-Canada

Julie Harrison-Au



To better understand the roles of the individuals who will be interacting with exponential technologies in an intelligent mine, we explore the following different facets of these personas' profiles:

- Future roles and responsibilities within the Nerve Centre
- Skills needed to achieve new work outcomes
- Relevant digital tools typically associated with intelligent mining and a Nerve Centre
- A glimpse into what a typical day in their lives could look like

One of the hallmarks of these roles of the future is that they'll likely draw on familiar components of work but put them together in new ways to create a job that's never been done before. As mining companies continue to progress towards becoming truly intelligent mining organizations, roles will continue to evolve. Understanding how work needs to change to quickly adapt to unforeseen circumstances and leverage technology to ensure more meaningful and safe work can help the industry transform and overcome disruption.

China Coal & Mining Expo 2021

China's 19th International Technology Exchange & Equipment Exhibition on Coal & Mining

Date: 26-29 October, 2021

Venue: New China International Exhibition Center (NCIEC)
Beijing, China

Host:
China National Coal Association

Co-host:
China National Coal Group Corp.

Organizers:
Together Expo Limited
China Coal Consultant International

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Intelligent mining technology

This article analyzes the current research status and development trend of intelligent technologies for underground metal mines in China, where such technologies are under development for use to develop mineral resources in a safe, efficient, and environmentally friendly manner. We analyze and summarise the research status of underground metal mining technology at home and abroad, including some specific examples of equipment, technology, and applications. We introduce the latest equipment and technologies with independent intellectual property rights for unmanned mining, including intelligent and unmanned control technologies for rock-drilling jumbos, down-the-hole (DTH) drills, underground scrapers, underground mining trucks, and underground charging vehicles. Three basic platforms are used for intelligent and unmanned mining: the positioning and navigation platform, information-acquisition and communication platform, and scheduling and control platform. Unmanned equipment was tested in the Fankou Lead-Zinc Mine in China, and industrial tests on the basic platforms of intelligent and unmanned mining were carried out in the mine. The experiment focused on the intelligent scraper, which can achieve autonomous intelligent driving by relying on a wireless communication system, location and navigation system, and data-acquisition system. These industrial experiments indicate that the technology is feasible. The results show that unmanned mining can promote mining technology in China to an intelligent level and can enhance the core competitive ability of China's mining industry.

INTRODUCTION

With the world's rapid economic development, the demand for mineral resources is increasing. It has been forecast that the depth of more than 33% of the metal mines in China will reach or exceed 1000 m within the next decade. Deep underground mining will become the trend of metal mining in China[1]. To overcome the disadvantages of traditional mining methods, such as excessive resource consumption, poor operating environments, low production efficiency, high safety risks, high production costs, and severe pollution, it is essential to develop an intelligent mining technology for underground metal mines that provides complete safety, environmental protection, and efficiency[2,3]. Some developed countries have done a great deal of work in the field of intelligent mining for underground metal mines over many years, and thus have considerable experience in this field. At the beginning of the 21st century, Canada, Finland, Sweden, and other developed countries made plans for intelligent and unmanned mining. At the Stobie Mine, an underground mine belonging to the International Nickel Company of Canada, Ltd. and a typical example of such an automated mine, mobile devices such as scrapers, rock drills, and underground mining trucks are operated remotely and workers can operate the equipment directly from the central control room on the surface[4]. According to the Canadian government's 2050 long-range plan, Canada intends to transform one of its underground mines in the northern part of the country into an unmanned mine. The plan states that all devices will be controlled from Sudbury via satellite in order to achieve intelligent and unmanned mining. Another intelligent mining program covering 28 topics – including the real-time process control of mining, real-time management of resources, construction of a mine information network, and application of new technology and automatic control – was carried out in Finland. Sweden has developed the Grountecknik 2000 strategic plan for mine automation[5-7], and veteran mining equipment companies such as Atlas Copco are actively developing a series of unmanned underground

mining equipment and related control systems that can be used to implement the strategic plan. One of the most famous institutes in unmanned vehicles, the Commonwealth Scientific and Industrial Research Organization of Australia, is making great efforts to achieve the intelligent mining of underground mines, with a particular focus on the unmanned control of various types of equipment[8].

Although these developed countries have already invested a considerable amount of time and money into the study of intelligent mining, only a few related studies have been carried out in China, especially in the field of intelligent equipment and plat forms. In order to rapidly advance its intelligent mining capabilities, China is supporting many intelligent mining projects, including the Key Technology and Software Development for Digital Mining project and the High-Precision Positioning for Underground Unmanned Mining Equipment and Intelligent Unmanned Scraper Model Research project. In particular, a project titled Intelligent Mining Technology for Underground Metal Mines was established during the 12th Five-Year Plan, in order to promote intelligent mining technology to a certain extent. This article introduces several research achievements and their applications in this project. Trackless mining equipment such as rock-drilling jumbos, down-the-hole (DTH) drills, underground scrapers, underground mining trucks, and underground charging vehicles have been developed using intelligent technologies. Suitable communication techniques, sensors, artificial intelligence, virtual reality, information technology, and computer technology for mining equipment and platforms have been implemented. The experimental results indicate that some of the system's functionalities are innovative and show good performance.

INTELLIGENT MINING

Mining is one of the oldest industries in the world. Mining production techniques have passed through a rapid change from artificial production, mechanised production, and on-site remote-control production, to intelligent and fully automated production. In order to move the mining industry forward, mechanization tools have been developed, single-equipment and independent systems have been automated, and the entire mining production process has been highly automated[9]. By integrating information technology with the industrialization of mining technology, intelligent mining technology has been rapidly developed, based on mechanised and automated mining, as shown in **Figure 1**. This has resulted in the gradual upgrading of intelligent processes in mining equipment; unmanned and centralised mining equipment have now entered the stage of practical application, which will significantly advance the automation and information technology used in mining[10].

Integrated communication, sensors, artificial intelligence, virtual reality, information technologies, computer technologies, and unmanned control equipment were combined in order to achieve intelligent mining technologies, as shown in **Figure 2**. Such technologies are based on precise, reliable, and accurate decision-making and production process management through real-time monitoring; they allow mine production to be maintained at the optimum level, and lead to improved mining efficiency and economic benefits. In this way, green, safe, and efficient mining can be achieved.

Taking a typical trackless mining technology as an example, intelligent mining technology can be divided

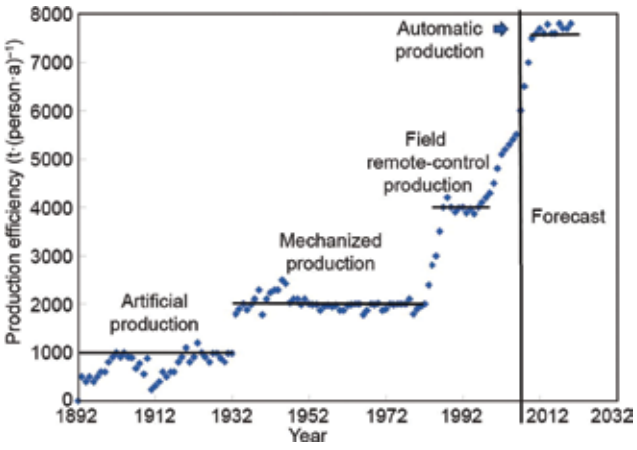

Figure 1: A comparison of production efficiency and mining technology development.

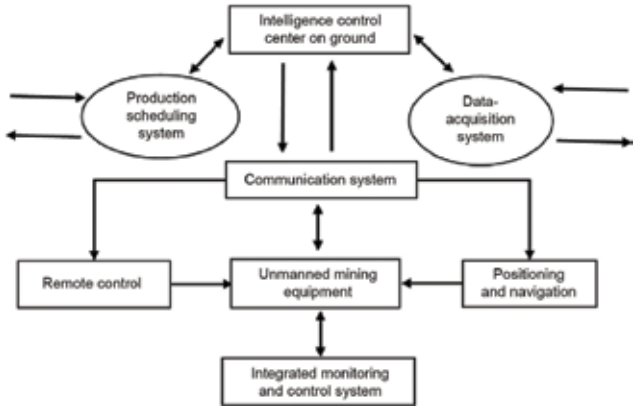

Figure 2: The fundamentals of intelligent mining.

into three layers – the control layer, transport layer, and executive layer[11].

As shown in **Figure 3**, the executive layer mainly consists of trackless mining equipment such as rock-drilling jumbos, DTH drills, underground scrapers, underground mining trucks, or underground charging vehicles. The transport layer mainly includes a ubiquitous information-acquisition system, wireless communication system, and precise positioning and intelligent navigation system. The control layer is designed as a system-level platform and is responsible for intelligent mining process scheduling and control. This is the core of the entire system because all intelligent mining-related functions and control ideas are implemented through this platform. First, a reasonable mining plan is designed by analyzing the reserves of mine resources and geological conditions in combination with the underground production schedule. Next, an intelligent scheduling and control platform is developed. Control instructions for the equipment are sent through the transport layer to a specific piece of equipment in order to perform a mining task at a specific position and time. Within the executive layer, the control layer collects current information on the tunnel and basic information about the vehicle in real time; this information can be used to determine the location of the equipment or adjust it at any time until that entire stage of the mining plan is successfully completed.

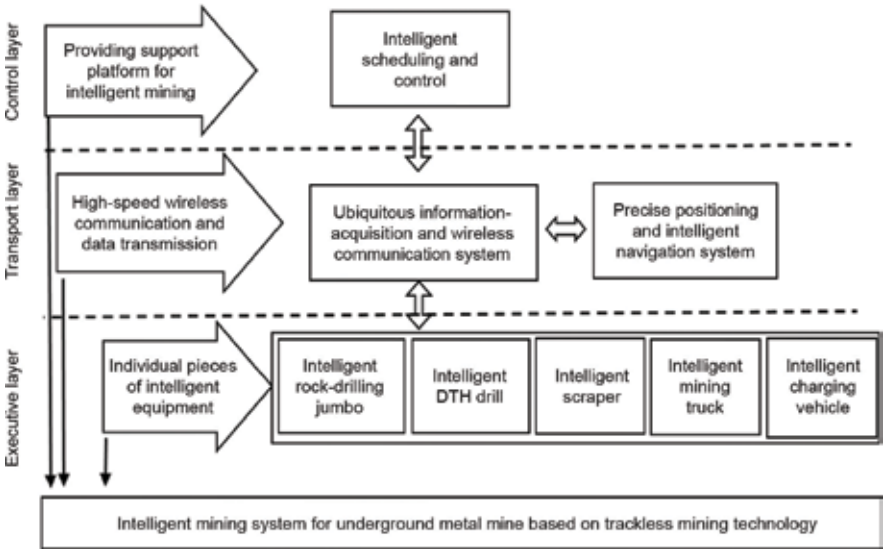

Figure 3: A diagram of intelligent mining technology.

UNMANNED EQUIPMENT

Intelligent trackless mining technology is based on intelligent unmanned equipment at the executive layer, such as rock-drilling jumbos, DTH drills, underground scrapers, underground mining trucks, or underground charging vehicles. The functions of intelligent and unmanned mining equipment differ according to the different tasks each piece of equipment must carry out.

Rock-drilling jumbo Intelligent

Rock drilling is the key process in mining, and plays an especially important role in productivity, cost, and efficiency. Different geological conditions require different mining methods, and different methods require different types of rock drilling. A hydraulic rock-drilling jumbo is needed for medium-length hole drilling (i.e., depth of 20-30 m, diameter of 60-100 mm)[12]. An intelligent and unmanned rock-drilling jumbo has been designed to support intelligent mining technology and efficiently complete drilling work.

Remote control and a virtual-reality display were the first basic technologies implemented in the unmanned hydraulic rock-drilling jumbo. **Figure 4** shows the initial unmanned control platform for the jumbo on the surface. The virtual prototype display system, including on-site audio and video signals, is well-integrated in order to increase the feeling of immersion while performing remote-control operations.

Figure 4: Remote control platform on the surface with on-site audio and video signals.

Furthermore, the rock-drilling jumbo is autonomously controlled and operated in the tunnel under the guidance of a positioning and navigation system. By coordinating the positioning system and altitude control system, the jumbo can achieve autonomous driving to the location from the dispatch layer. This is a major step toward achieving continuous operation without interference. Given the coordinates of the drilling-hole position in the three-dimensional (3D) digital map of the mine, the identification of the stope top and floor and the accurate positioning of the rock-drilling system can be achieved independently. This provides a basis for unmanned operation. The intelligent control flow diagram is shown in **Figure 5**.

The rock-drilling parameters are independently adjusted according to the rock conditions. The intelligent rock-drilling jumbo (shown in **Figure 6**) is equipped with components for intelligent blockage prevention, rock-characteristic acquisition, and frequency matching; an automatic rod function; and a fully automatic drill-pipe bank. The hole-blasting parameters are specified independently, according to the scheduling system that is used, in order to ensure continuous drilling.

Intelligent DTH drill

A DTH drill is needed when the rock-drilling jumbo cannot be used, such as in an ultrahigh section with large-bore deep-hole drilling (i.e., depth greater than 30 m, diameter of /100-150 mm). The disadvantages of the DTH drill are its lack of safety, low ease-of-operation design considerations, insufficient matching of structure and parameters, oil leakage, and seepage. The existing DTH drill has low automation and is inefficient[13]. Therefore, an intelligent unmanned DTH drill was designed to support the intelligent mining technology.

The first features that were implemented in the new DTH drill were intelligent autonomous driving and a hole-positioning function. Like an intelligent rock-drilling jumbo, an intelligent DTH drilling machine should be capable of drilling holes in a predetermined position according to the requirements of the mining design. An autonomous driving function is needed for when the equipment is in drilling operation. The structure of a four-wheel independent steering system is shown in **Figure 7**; this system was developed and applied to the new DTH drilling machine in order to ensure free turning in a narrow space. Another feature to be applied was the automatic matching of the rock-drilling parameters with intelligent control.

The effect of the working parameters on drilling efficiency was analyzed by evaluating drilling parameters such as axial thrust, rotary speed, rotary torque, impact pressure, impact frequency, and rock-drilling pressure. A theoretical

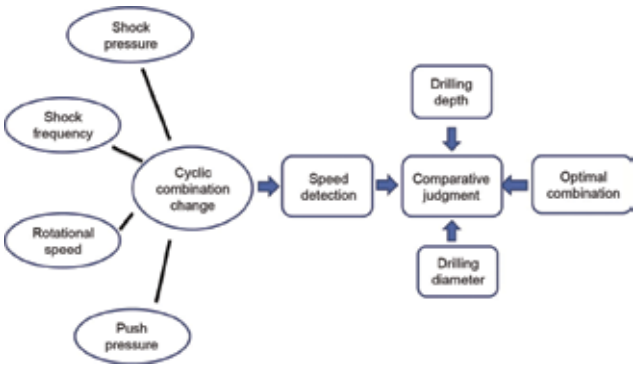

Figure 5: Intelligent control flow diagram of hydraulic drilling.

Figure 6: Intelligent rock-drilling jumbo.

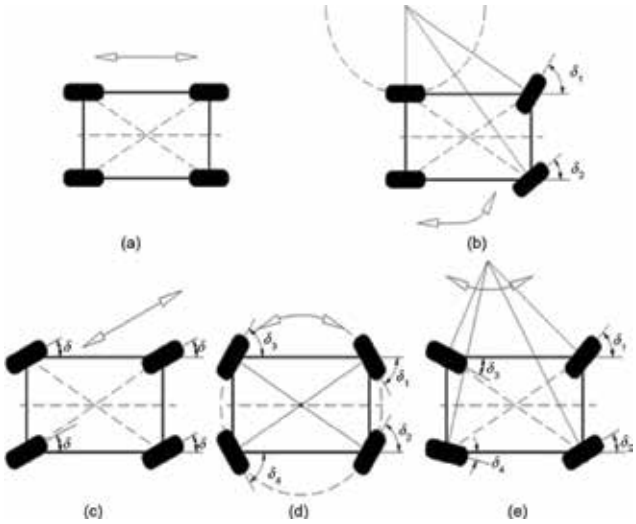

Figure 7: The structure of a four-wheel independent steering system. (a) Straight driving; (b) front-wheel steering; (c) oblique driving; (d) point-turn motion; (e) four-wheel steering. d: the angle of the four wheels; d1 and d2: the angles of the forward wheels; d3 and d4: the angles of the backward wheels.

calculation model or empirical formula was deduced for each parameter selection, and the key parameters affecting drilling efficiency were determined. The optimal drilling parameters for the matching method were selected, including air pressure, gas volume, and propulsion force. The drilling efficiency was then optimised by intelligent control of the operation parameters.

The third feature was anti-deviation control technology, as shown in **Figure 8**. Blasting can be directly affected by many factors, such as the positioning accuracy of the drill

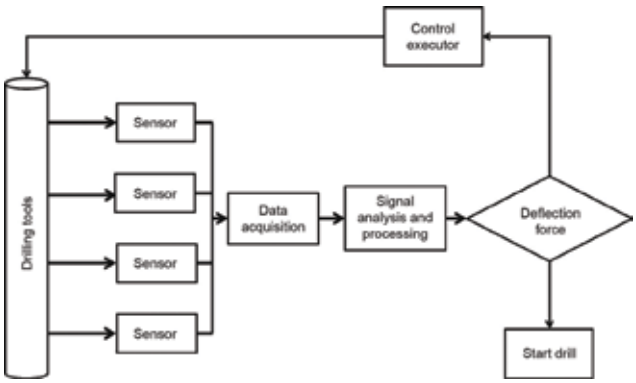

Figure 8: Anti-deviation control flow diagram of the drilling rod.

point, depth of the hole, and declination of the hole. An intelligent DTH drill should control the drill pipe in real time in order to avoid large errors that will affect the subsequent blasting[14].

The final features were multiple drill-pipe storage, automatic sorting, and anti-blocking resistance rod technology. **Figure 9** shows the operation of an intelligent DTH drilling machine. The characteristics of the DTH drill determine that if the hole is 60 m deep, then at least 40 drill pipes are needed every time. Therefore, multiple drill-pipe storage and automatic sequencing feed-rod technologies were designed in order to improve the operational efficiency of the equipment. By analyzing the mechanism of the drill rod, the parameters of the control function of the DTH drill rod can be established in order to avoid blocking of the rod during the automatic sorting process.

Intelligent underground scraper

Since the first successful testing of the ST-5 scraper by Wagner in the 1960s, scrapers have been widely used in underground mining because of their high efficiency, flexibility, maneuverability, and low cost. With the rapid development of electronic and information technology, intelligent control technologies for the under-ground scraper have been rapidly developed. The operation of the underground scraper has gradually changed from manual to remote control. At present, it is known as the fourth-generation autonomous scraper[15-18].

Figure 9: Operation of the intelligent DTH drilling machine.

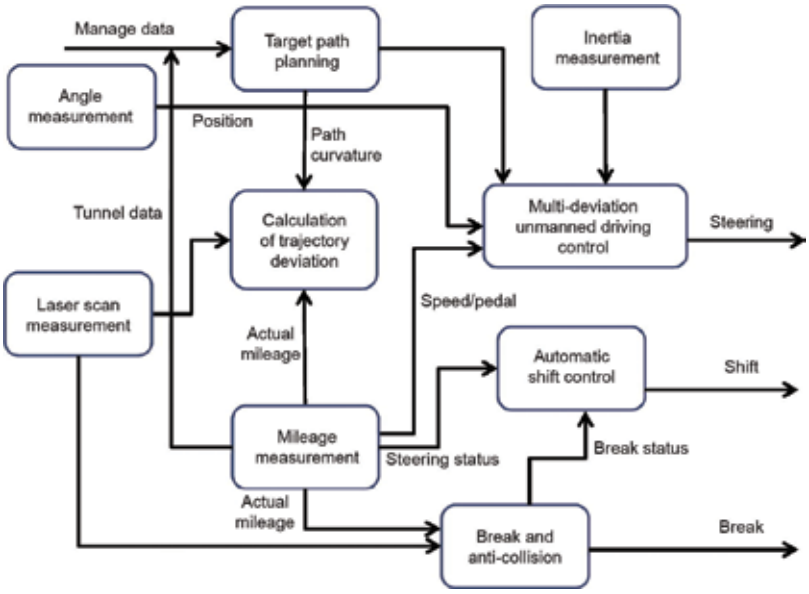

Figure 10: The driving algorithm of an unmanned scraper.

The main task of a scraper is the repeated transportation of ore between the loading point and the dumping point. Therefore, the first task of an intelligent scraper is to achieve unmanned driving during ore transportation. Recognition of the tunnel environment is achieved by a body-loading sensor, and a positioning and navigation system is used to assist in the operation of the scraper. **Figure 10** shows the driving algorithm of an unmanned scraper.

Another typical task of a scraper is shoveling ore, which may include automatic weighing. The main purpose of automatic weighing is to obtain real-time data and automatic statistics for the ore. Automatic weighing technology can obtain statistics for the class report, daily report, and monthly report, and can transfer this data to the central control room through the communication network. It can also enable managers to grasp the status of underground production in real time.

An intelligent underground scraper can automatically drive to a preset fixed point in order to dump ore, by relying on the positioning system, navigation system, and wireless communication system after the dispatch instruction has provided a specific dumping point. This is the basis for continuous unmanned mining with scrapers. An intelligent underground scraper does not operate within the view of its operator, and failure information cannot be observed in real time; therefore, it must be able to perform in an intelligent manner using the fault-diagnosis function[19,20]. The vehicle should be able to follow remote-control instructions from the surface such that the scraper can be controlled at any time. **Figure 11** shows the intelligent underground scraper and its remote-control platform.

A vehicle-control system combines the environmental information that is collected by various types of sensors. A machine-learning algorithm uses the vehicle state acquired by the articulated angle sensor to calculate the target output and control the actuator movement. **Figure 13** shows the distribution of sensors for unmanned driving. The system does not need the absolute coordinates of the vehicle; an unmanned driving function can still be achieved[21].

The first double-power transmission mining truck for use in an underground mine was designed in China for a full load of 35 t, a speed of 25 km h^{-1}, and a maximum climbing slope of 21.8%, as shown in **Figure 14**. In addition to its unmanned driving function, the truck is capable of vehicle lane-space detection and intelligent auxiliary driving; it also has a remote-control function. The fully loaded autonomous operation speed is higher than 10 km-h^{-1}.

Intelligent underground charging vehicle

In underground mining, the four main processes are drilling, blasting, loading, and transportation. As a charging vehicle is essential for blasting, it is particularly important to develop automation operation for a charging vehicle. An underground charging vehicle is an integrated mechanical and electrical product that performs raw-material transportation, explosive mixing, and gun-hole loading. It has the characteristics of a compact structure, a high degree of automation, and a wide application range.

Figure 11: An intelligent underground scraper and its remote-control platform on the surface.

Figure 12: A system block diagram of the double-power transmission underground mining truck.

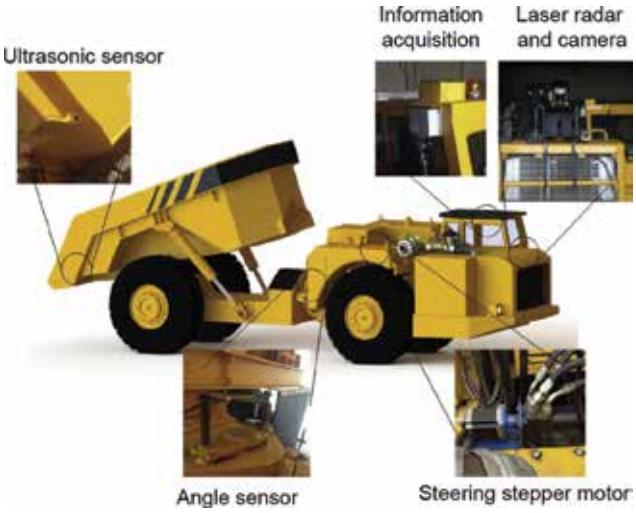

Figure 13: Distribution of the sensors for unmanned driving.

Figure 14: An intelligent underground mining truck.

An intelligent charging vehicle system is shown in **Figure 15**. The pipe-reeling speed, pipe-feeding speed, and charging speed can be digitally controlled, and the reeling and feeding speeds are automatically matched with the charging speed and hole diameter. A fully coupled charge is achieved in order to improve the blasting effect. The safety protection system performs online monitoring and fault diagnosis of the charging system. Remote fault diagnosis, remote scheduling, remote management, and the upload and delivery of production tasks and data can be easily achieved using an intelligent scheduling system on the surface.

A charging vehicle uses wireless and intelligent control technology to achieve remote control and intelligent hole searching. The start and stop of a charging system, key process parameters, temperature, pressure, and flow are displayed on the remote control. The automatic feeding and reeling system, automatic delivery, charging of hole depth, and single-hole charging during the delivery of pipeline are designed to support intelligent charging[22].

A wireless remote-control technology is used for the vehicle, and remote control and complete unmanned driving can be achieved using a positioning and navigation system and a wireless communication system. Coordinates can be accepted from a scheduling system, and the vehicle can then autonomously drive to the designated location point of the hole and complete the charge. **Figure 16** shows the operation of a charging vehicle in a tunnel.

BASIC SYSTEM PLATFORMS

Positioning and navigation platform

The positioning and navigation platform consists of a precise positioning system and an intelligent navigation system. The precise positioning system can provide position and altitude information to the underground mining vehicle. The intelligent navigation system consists of two key modules for path planning and path tracking. The path-planning module helps to find the navigation path of the mine vehicle according to the dispatch instructions, and the path-tracking module helps to automatically move the mine vehicle to the target position along the planning path.

Taking a point and line as the basic geometric representation, a two-dimensional (2D) navigation map was built, and accurate drawing of the underground map and detailed incorporation of the navigation information were achieved. This provides a basic map platform for the precise positioning and intelligent navigation of the mining equipment. Real-time high-precision positioning information was obtained by combining laser-positioning data with ultra-wide-band (UWB) auxiliary positioning data, as shown in **Figure 17**. The positioning system consists of a high-precision laser-positioning base station system, a vehicle machine vision system, and UWB wireless positioning technology. The positioning accuracy can reach up to 100 mm. A reasonable and smooth planning path can be searched for on the electronic map using the path-planning module, based on the breadth of the first search, the dichotomy, and the symmetric polynomial curve-smoothing method. Hybrid architecture and a real-time reflection control system were used to achieve accurate tracking of the planning path using the positioning information[23,24].

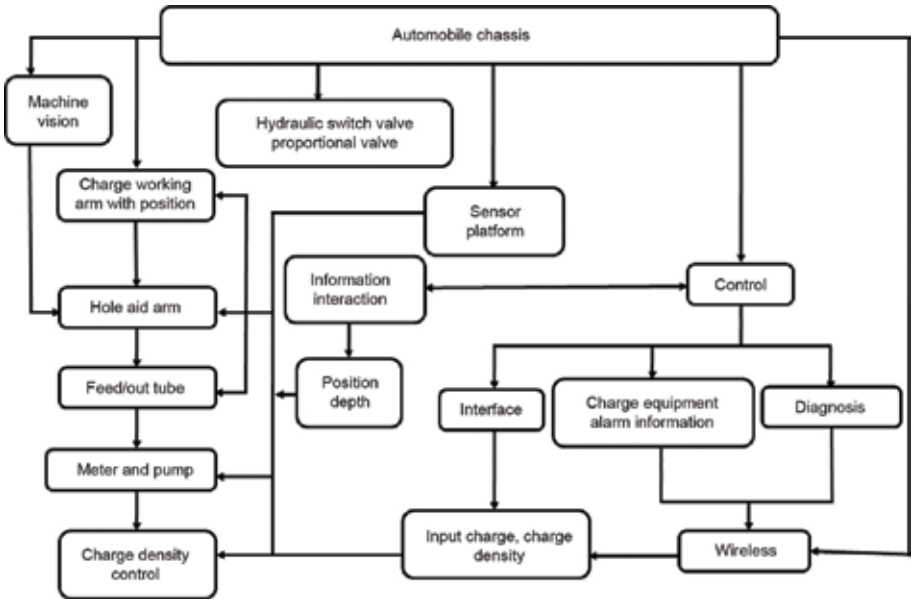

Figure 15: Design of an intelligent charging vehicle system.

Figure 16: An intelligent underground charging vehicle.

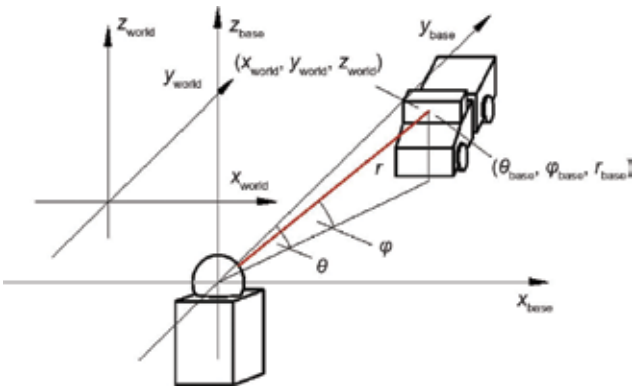

Figure 17: Positioning information obtained by the laser system and UWB system. xworld-yworld-zworld is the world coordinate system; xbase-ybase-zbase is the local coordinate system; h is the pitching angle and u is the roll angle; r is the distance between the laser and the equipment; and (hbase, ubase, rbase) is the location of the equipment in the xbase-ybase-zbase coordinate system.

Information-acquisition and communication platform

The main function of the information-acquisition and communication platform is to obtain intelligent mining data. The underground intelligent equipment, scheduling and control system, information-acquisition system, and data communication system work together using the same communication protocol within the framework of intelligent mining technology, as shown in **Figure 18**. Thus, the extendibility, reusability, and standardization of intelligent mining technology have been achieved. Independent underground functions, geographically dispersed sensors, trackless equipment, production equipment, and local control systems were combined to form the basis of intelligent mining technology for an underground metal mine.

The basic functions are provided by a ubiquitous underground information-acquisition and control device. The real-time high-precision acquisition and rapid reliable transmission of analog, digital frequency, and video and audio frequency are achieved using a high-frequency embedded processor and distributed architecture, as shown in **Figure 18**. The architecture can be configured with various pieces of underground equipment, a digital mine system, a mining production system, and an environmental monitoring system, and information can be uploaded efficiently. A non-differential data-transmission channel is established between the equipment and the communication system using CAN, RS485, Ethernet, and other data-transmission methods. A multilevel composite network architecture based on distributed technology permits the achievement of seamless roaming and redundant transmission technologies between the base stations during the movement of the underground vehicle. The underground wireless network has no blind area coverage and has a high transmission rate and exceptionally reliable communication. This network provides a fast, efficient, and reliable data-supporting platform for the remote operation of mining equipment[25].

Fast mobile switching of underground wireless communication terminals is very important, as shown in **Figure 19**. Multi-frequency cross-networking was used to overcome the communication interruption problem for underground equipment in motion. Seamless mobile handover of the operation process of intelligent equipment was achieved. The communication system overcame the communication-rate bottleneck of traditional wireless devices and achieved a wireless link

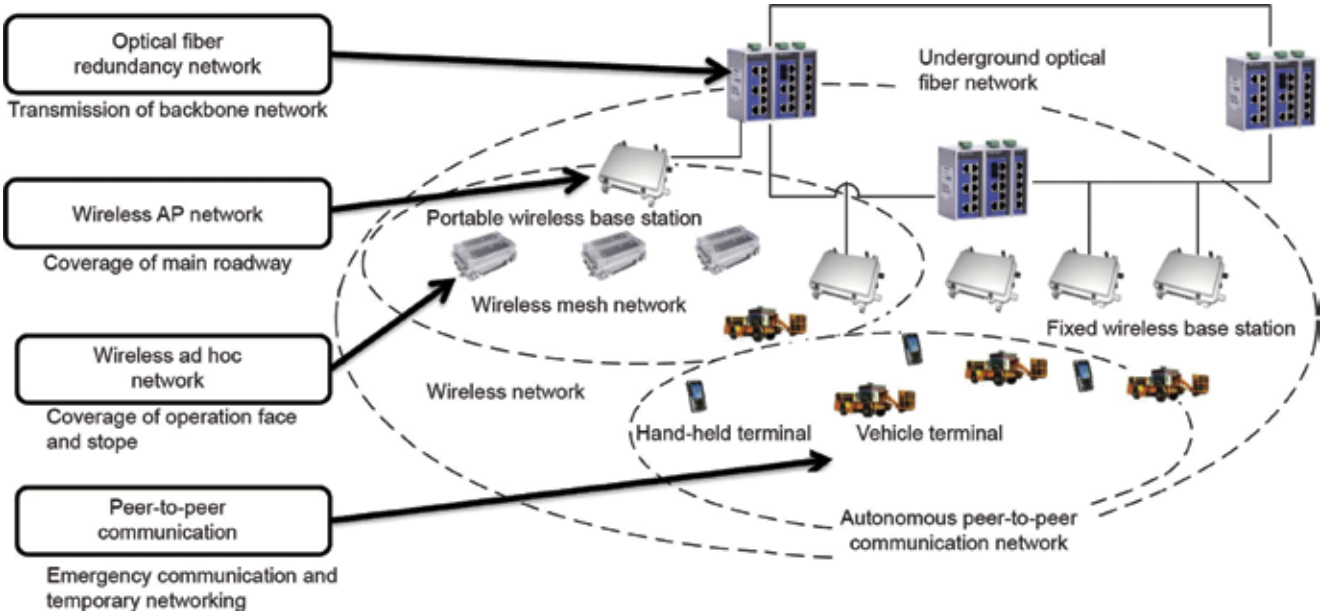

Figure 18: Architecture of an underground wireless communication system. AP: access point.

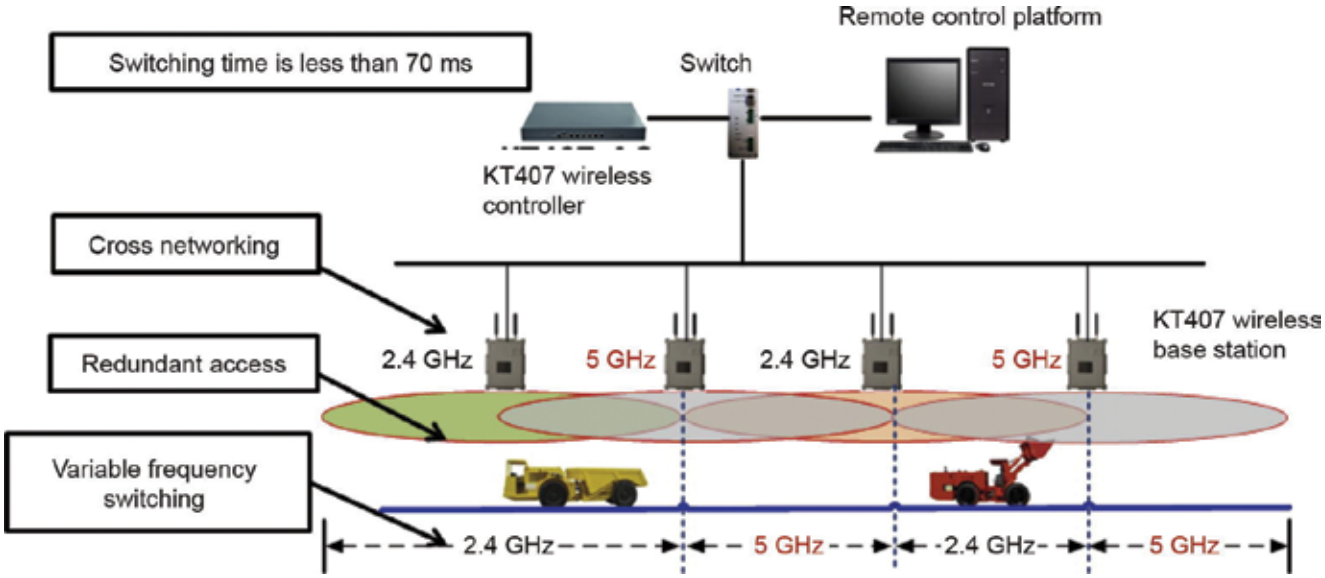

Figure 19: Fast mobile switching of underground wireless communication terminals.

rate of up to 600 Mbit s^{-1} using 802.11n technology. The automatic identification, classification, and transmission of underground intelligent equipment business data were fully supported. A stable network communication platform was thus provided for the remote control and autonomous operation of the equipment.

Scheduling and control platform

The intelligent scheduling and control system plays an important role in the performance of mining. An intelligent software platform and management center are key features of an intelligent mining system. Based on the actual demand of underground metal mine production scheduling and process control, the intelligent dispatch of an underground metal mine based on a data warehouse was achieved by implementing key technologies such as the organization and management of multisource data, 3D visualization of resources and mining environment, dynamic simulation of production processes, and intelligent dispatch and control systems.

The scheduling and control system also performs the functions of organizing and managing mine data, modeling and updating resources, identifying the mining environment, automatically producing the mining plan, and intelligently dispatching the production process[26]. The platform can provide information on the 3D environment simulation, simulation of equipment condition, real-time status of equipment, intelligent scheduling of equipment, device real-time video, and location. An integrated intelligent scheduling and control platform for intelligent mining was built using this system, as shown in **Figure 20**.

EXPERIMENT

An intelligent mining system was built in the middle part of the Fankou Lead-Zinc Mine in China. Centralised control, high-speed communication, autonomous driving, and the intelligent operations of an underground scraper, a mining truck, a rock-drilling jumbo, and a DTH drill were tested. The framework diagram is shown in **Figure 21**.

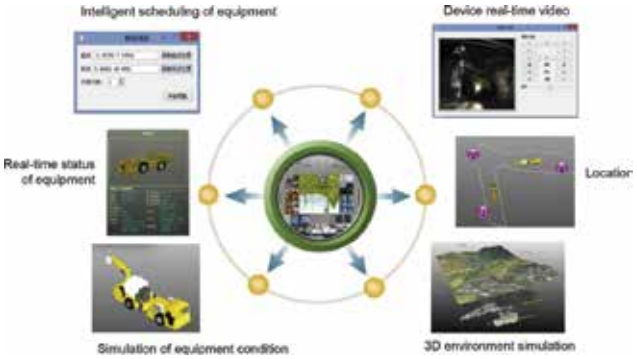

Figure 20: Diagram of the intelligent scheduling and control platform.

The industrial field-test results show that the integrated technology of underground intelligent mining based on unmanned equipment is especially useful. The intelligent

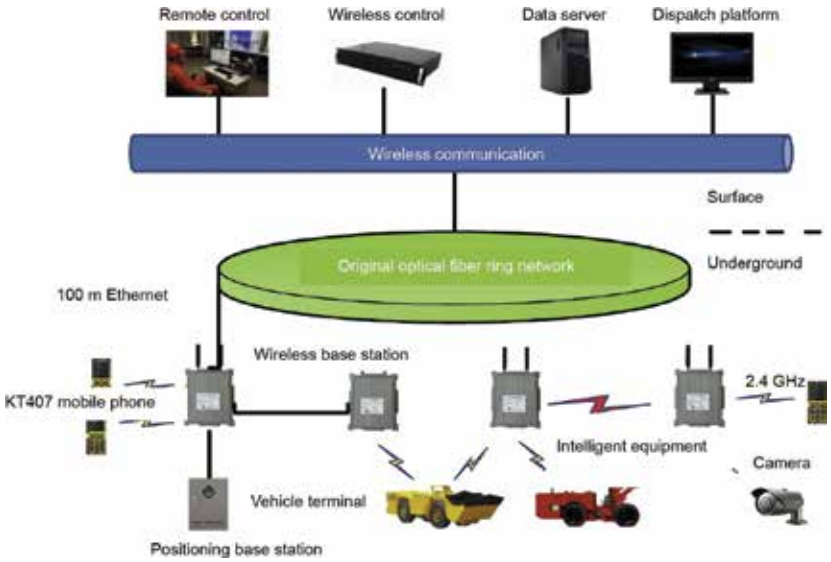

Figure 21: A framework diagram of an intelligent mining system test in an underground metal mine.

dispatch and control system runs stably and can achieve the remote monitoring and synchronous 3D-operation display of the down-hole equipment. The positioning and navigation system is capable of navigating the underground environment and operating the equipment. The path planning is reasonable, and position tracking of the equipment was achieved with 100 mm accuracy. The performance of the ubiquitous information-acquisition and communication system was excellent.

The intelligent underground scraper had many operating modes including autonomous, remote, and manual driving, and carried out the functions of fixed-point unloading and autonomous weighing.

Autonomous driving and intelligent operation of the mining truck, charging vehicle, DTH drill, and rock-drilling jumbo were achieved. Thus, intelligent mining technology for an underground mine based on unmanned equipment was verified.

CONCLUSIONS

Intelligent mining technologies for underground metal mines are the concrete embodiment of China's national policy of upgrading traditional industries through modern and cutting-edge technologies. Intelligent mining technologies integrate the applications of high-end technologies based on automation, information technology, digital and artificial intelligence, and many other new technologies, through multidisciplinary and multiple technology integration. Intelligent mining not only improves the effectiveness of mining equipment and the intelligent monitoring of mining processes, but also significantly improves mining efficiency, thus reducing the mining cost, and improving the competitive ability of mining enterprises. At the same time, intelligent mining can reduce the number of field operations and the risk of disasters. In addition, intelligent mining is an effective way to achieve cleaner production and sustainable development of mines. In intelligent mining, the loss and dilution of ore mining are effectively controlled, and the amount of waste ore produced by mining is mini mised, while the recovery rate is maximised. Thus, intelligent mining can effectively reduce the discharge of mine solid waste and significantly improve the utilization rate of mineral resources. It can promote the efficient, safe, green, and sustainable development of mineral resources.

At the same time, intelligent mining will promote the development and enhance the core competitiveness of China's mining industry. The future application trend for underground intelligent mining is the economic, safe, and efficient mining of underground mines by relying on large-scale unmanned equipment, intelligent systems, and integrated optimal scheduling and production management. Potential for technology development lies in the combination of artificial intelligence and automatic mining. Of course, many shortcomings must still be remedied in the mining system; for example, the speed of unmanned equipment needs improvement. The reliability of the whole system needs to be verified by industrial experiments in order to meet the requirements of practical application.

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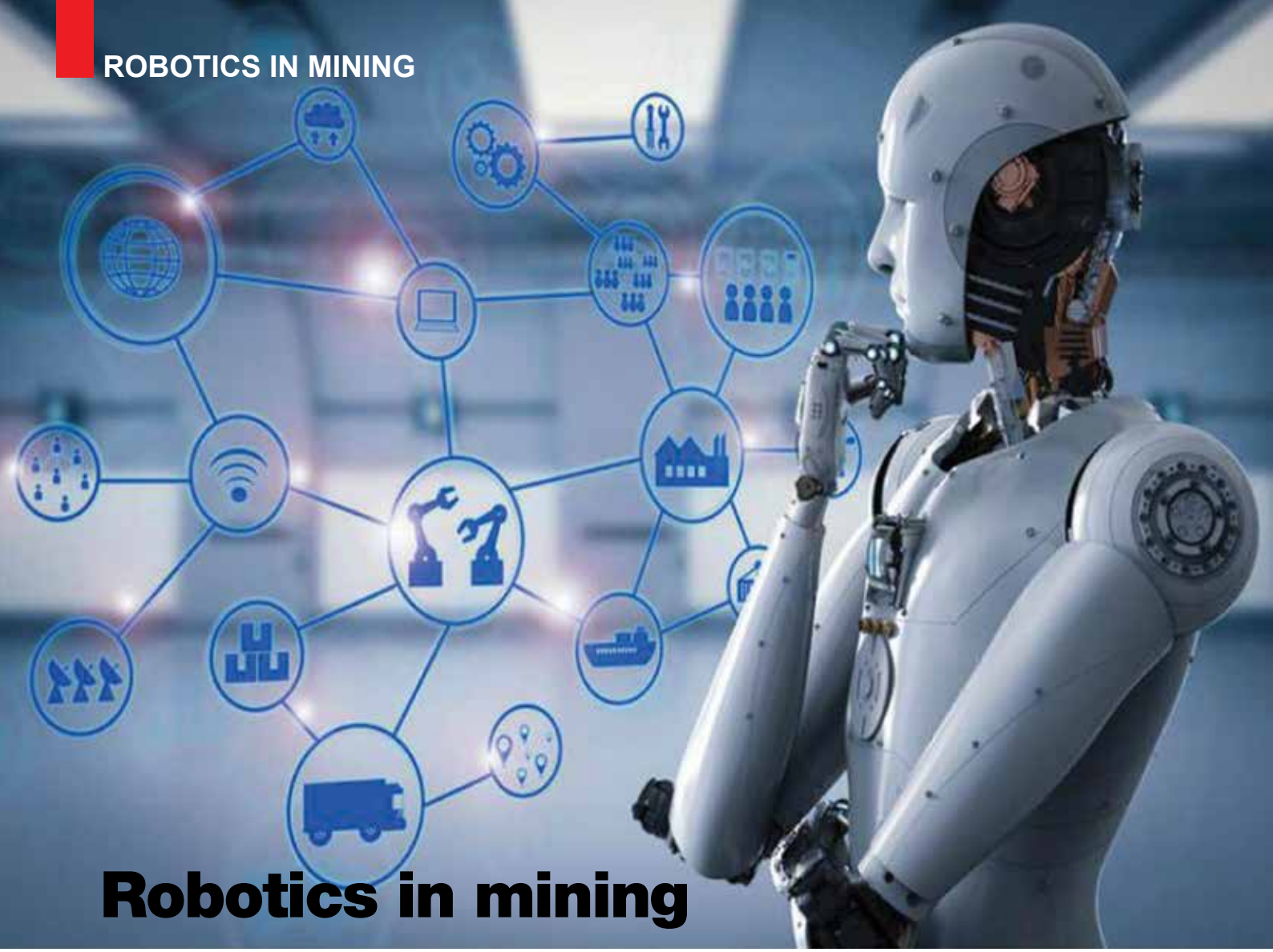

Robotics in mining

Over the past few decades, automation in the mining industry has gradually reduced the role played by the miner, edging them further and further away from danger. Recent breakthroughs in autonomous robotics have promised to take this process to its logical conclusion. Major players in the industry have invested heavily over the years in their surface mining activities but underground operations are in some ways still playing catch up.

So how long it will be before humans are eliminated entirely from the physical side of mineral extraction ?

Trevor Barratt Managing Editor looks at a recent presentation paper that outlines the headway being made in Polish underground mines.

AUTOMATION AND ROBOTIZATION OF UNDERGROUND MINING IN POLAND

The article concerns the condition of automation and robotization of underground mining in Poland. Attention has been focused on the specific character of the mining industry. This limits the possibility of using robotization, and sometimes even the mechanization of certain processes. In recent years, robotic and automated machines and machine system solutions have been developed and applied in Poland. They are autonomous to a various degree, depending on the branch. The type of automation and artificial intelligence depends on the specific use. Some examples presently being used include the MIKRUS automated longwall system and autonomous device(s) for breaking rocks or mining rescue work. In Poland, fully automated plow systems produced by foreign companies are also used. Companies in Poland and international research centres are also actively engaged in the development of underwater and space mining. where robotization is of key importance. Research is also being undertaken by Robotics in Mining, euRobotics and PERASPERA as well as Space Mining Conference.

1. INTRODUCTION

Underground mining exploits various useful minerals. The exploitation and transport of minerals are mostly mechanized. Some machines are automated and, to varying degrees, autonomous[1,2]. In Poland, the largest market for underground mining machinery is the mining of hard coal. This is followed by mining for copper ores and other raw materials, such as rock salt or zinc and lead ores. The share of mining for these other raw materials is small. Difficult conditions of machine operation have resulted in noticeable changes in the approach to safety and comfort at work. This is the reason for seeking a method to eliminate or reduce human participation in mining operations. The progress in mobile control and navigation techniques has led to an interest in automation and robotization. Measurable economic benefits have been obtained by using such solutions. Another important consideration is increasing the safety and comfort of underground workers. Robotization can contribute to enhanced safety when withdrawing people from the most threatened zones. These zones are where mining usually takes place. A separate and increasing need is using robots in underground rescue operations[3].

Coal mines are difficult workplaces, not only for humans, but also for machines. Natural hazards, limited space, a lack of natural light, dustiness, humidity, high temperature and mine atmosphere hinder mechanization. Despite these adversities, Poland boasts many solutions developed in national research centres in cooperation with machine manufacturers. The state of underground mining automation and robotization in Poland will be presented through several selected examples.

2. SOLUTIONS APPLIED TO MINING IN POLAND

In Poland, various solutions for mining machines and machine systems with varying degrees of autonomy are designed and manufactured. Several such examples will be briefly described.

2.1 MIKRUS Automated Longwall System

Raw materials found in coal seams are exploited by means of mechanized longwall systems[4]. Longwall systems are systems of compatible and cooperating machines that simultaneously carry out the process of mining (loading and hauling of mined rock) as well as securing the roof. The extraction from ever-thinner seams causes working conditions which make manual control difficult[5,6]. Therefore, automated longwall systems need to be developed. The American company Caterpillar Inc. is the leader in the field of automatic plowing systems. Their most advanced product, GH1600, is used by two coal companies in Poland. A competitive longwall technique is the shearer technology, which has been fully automated for use in thin seams. The KOPEX S.A. group (Katowice, Poland) has developed and constructed a longwall system for thin seams. Currently, the solution belongs to the FAMUR S.A group. The system, called MIKRUS ("midget" in Polish), is equipped with a GUŁ-500 (stands for Polish words głowica urabiająco-ładująca) cutting and loading head with two cutting drums. GUL-500 is moved by a longwall conveyor along the coal side wall by means of a cable system under the powered roof support units (**Figure 1**).

The whole complex is powered and controlled by an integrated system located on the surface of the mine (**Figure 2**). In addition, in the event of a failure, the complex is equipped with a central desktop at the operator's station, which is located in the haulage heading. Trouble-free, automatic, and optimal operation is ensured by the EH-WallControl (Elgór + Hansen WallControl) automation system. Information on the work of all longwall face machines is supplied to the automation system. Based on this information, the system generates signals to the control systems of machines (shearer, conveyors, support units, pumps). In the event that information about hazards or pre-emergency conditions appears in individual devices, the system signals it at the operator's workstation. If the permissible operating parameters are exceeded or pre-emergency conditions occur, the system will turn off individual devices or will stop the entire system. For security reasons, the operator can start up individual devices even if there is a risk of failure. Such a status is separately and clearly recorded.

All the data about the operation of longwall equipment are available in particular menus called on the operator's command and are visualized at his workstation. In the automatic work cycle, the operator only controls the speed of the loading cutterhead feed, while the work of other devices is controlled by the master system of the longwall automation complex. The operator can switch over to manual control and change the operating parameters of the devices at any time. The combination of the features of plow and longwall shearer systems in the MIKRUS complex translates into increased operational efficiency in low faces. Moreover, the use of advanced control and diagnostic systems has enabled the construction of a fully automated longwall complex. The MIKRUS longwall system for mining thin seams is a unique solution on a global scale. The MIKRUS longwall system allows for profitable and safe extraction in thin coal seams. Innovative solutions based on automation contribute to employees' comfort[7,8].

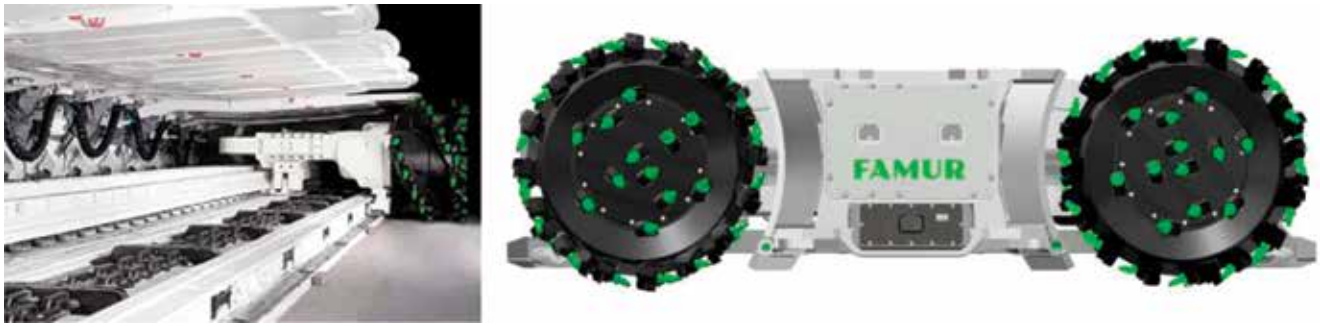

Figure 1: MIKRUS system produced by FAMUR S.A.

Figure 2: Cabin for monitoring the automatic operation of the MIKRUS system from the surface[8].

2.2 Mine Master Self-Propelled Mining Machines

In ore mines, such as KGHM Polska Miedź S.A. (Lubin, Poland), the useful mineral is usually mined by means of explosives. Self-propelled drilling machines are used for harsh operating conditions, characterized by an ambient temperature exceeding 35° Celsius and air humidity up to 98%. The machines are operated at depths ranging from 600 m to 1200 m, where there are strong saline watercourses, which force the use of subassemblies with high IP 67 (International Protection). In such extreme conditions, the human factor is increasingly often an unreliable element, so a chance to improve work efficiency is seen in the automation and monitoring of mining processes. Mine Master, in cooperation with the AGH University of Science and Technology, based on joint experiences in drilling process automation, designed two modular drilling machine monitoring systems. The system was implemented jointly with the machine user – KGHM Polska Miedź – which works on selected Face Master 1.7 machines[9,10,11]. Monitoring of drilling machines was first introduced for systems that have a decisive impact on achieving the assumed productivity by machines. In the case of Face Master 1.7 drill rigs, it was a system for monitoring the drilling parameters and drilling frame settings in accordance with the assumed blasting pattern (**Figure 3**). The natural consequence of monitoring was the implementation of systems for diagnosing the drive system and the hydraulic system of machines. Monitoring has control over the machine, not only during the process of drilling, but also when traveling to and from the workplace on roads with a slope of up to 15°.

Monitoring systems for drilling machines used in underground conditions of KGHM Polska Miedź, which successfully completed their tasks, include the following scope:

- Mapping of the blast pattern on the heading face and its visualization on the operator's panel.
- Repeatability of the drilling process in the face geometry.

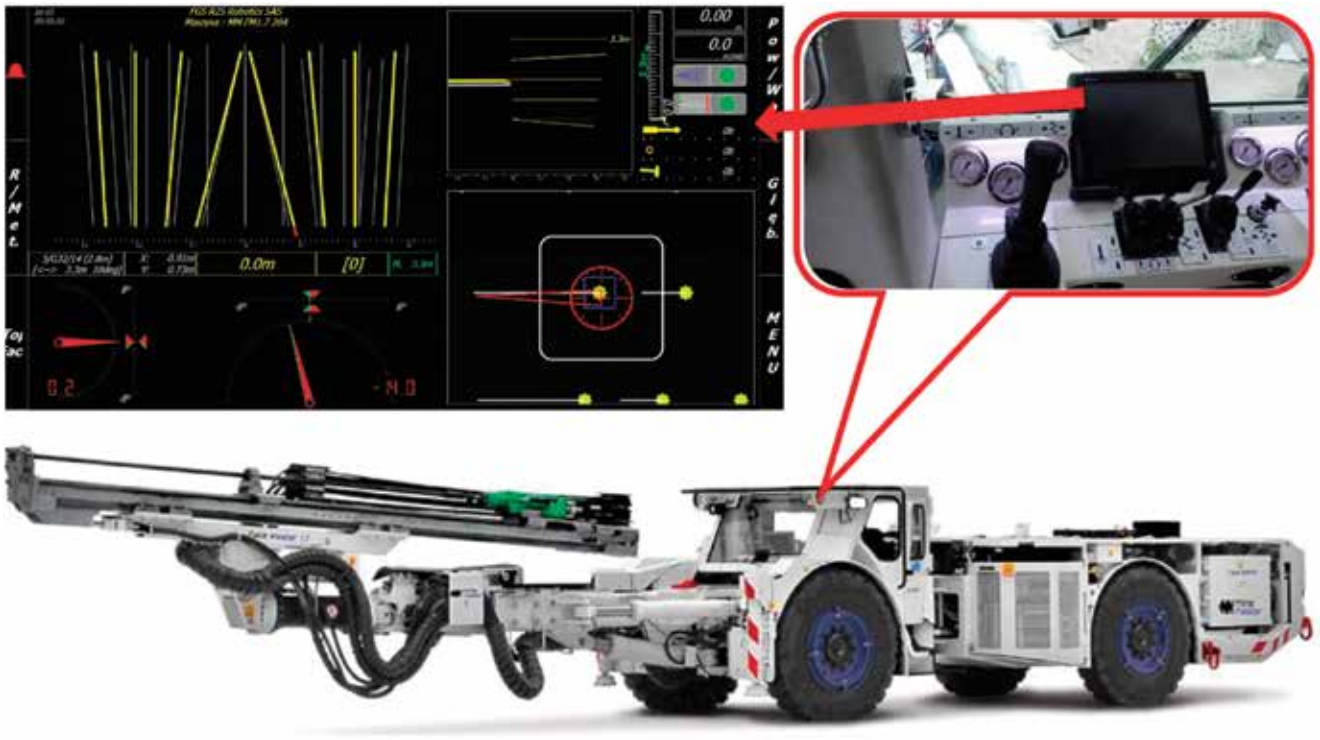

Figure 3: Face Master 1.7 machine with a control panel and a view of the Feeder Guide System (FGS) drill rig positioning system[9].

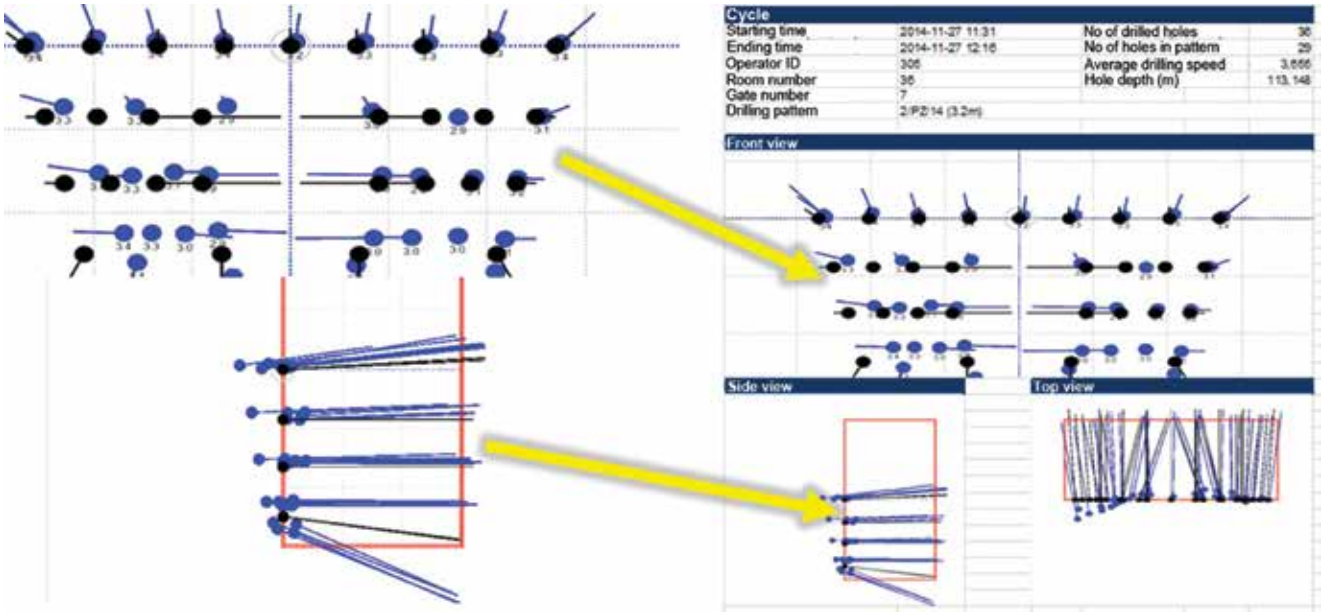

Figure 4: FGS report on drilling with a comparison of the assumed (black) with actually completed blasting pattern (blue)[9].

- Monitoring and control of drilling parameters.
- Quick diagnosis of the drilling system.
- Increased work efficiency.
- Recording of work done.
- USB or WiFi data transfer.
- Generating reports on the work performed (**Figure 4**);
- Work "in the background" of systems so that their possible failure will not limit the basic functions of the machines.
- Increasing the availability of machines through more precise and faster damage diagnostics.

The FGS system (Feeder Guide System) is the successor of the DMS system (Drilling Monitoring System). DMS monitored only drilling parameters, such as speed, depth, or pressure in the hydraulic system.

The basic element of the system is the operator's panel, which contains software that controls the drilling support process. The operator's panel is resistant to operating conditions and has a high-contrast display with built-in function buttons or a touch screen facilitating correct readings. The operator's panel is additionally equipped with an integrated USB port, which enables data transfer. Another element necessary for the proper operation of the FGS system is sensors, the basic task of which is to determine the drill rig's position between the positioning and measuring elements. Thus, it is possible to reflect the position of the drilling frame in the system and the control panel. The software allows employees to create 3D blasting patterns, including the preparation of previous patterns and their uploading via a USB flash drive. The FGS system allows obtaining one plane of the face regardless of the initial state. The length of individual holes is calculated by the system in such a way that they end in one plane. Obtaining this effect with manual control is not possible. The program for creating blasting patterns enables changing the direction of the excavation. The result is the program choosing the appropriate length of the holes. The FGS system in drilling machines has contributed to the improvement of drill rigs performance in the area where tests were carried out at Polkowice-Sieroszowice mine, KGHM Polska Miedź S.A. The FGS system has also enhanced work safety for persons staying in the faces. This repeatability in the drilling process results in the proper geometry of the face.

2.3 Famur Road header

Making drifts in underground mines is one of the most important processes. In most cases, headings are made with roadheaders controlled locally by the operator. This work is dangerous due to falling rocks, dust, noise, and temperature. It was, therefore, decided to withdraw the staff from the area of shearer operation and introduce systems for supervising and automating its work. Elgór-Hanses S.A., which is part of the FAMUR S.A. group(Katowice, Poland), developed and implemented a shearer remote control system. EH-RemoteHeadControl v2 is a system enabling the remote control of roadheaders designed for operation in particularly dangerous zones due to the risk of gas and rock outburst as well as rock burst hazards. The system allows the service staff to work in safe work conditions, as during the shearer operation, they stay in a non-hazardous area. The safety of underground miners is the most important issue of all matters related to the operation of underground mining plants[8].

The system consists of a few elements (**Figure 5**).

- Up to ca 50 m–100 m behind the shearer, a box with a laser shining parallel to the axis of the excavation is mounted on the roof. The laser position is corrected using a wireless remote control.
- The shearer has a set of devices for automatic positioning of the shearer in the heading. The devices include a set of cameras, sensors and a signal processing controller. A radar is used to communicate with the laser.
- In the safe zone outside the directly threatened area is an operator's workstation in the form of a cage with monitors with a remote-control panel. The operator's workstation is in the form of a cage with monitors and a remote-control panel located in a safe zone outside the directly threatened area.
- Diagnostic of head tools wear[12,13].

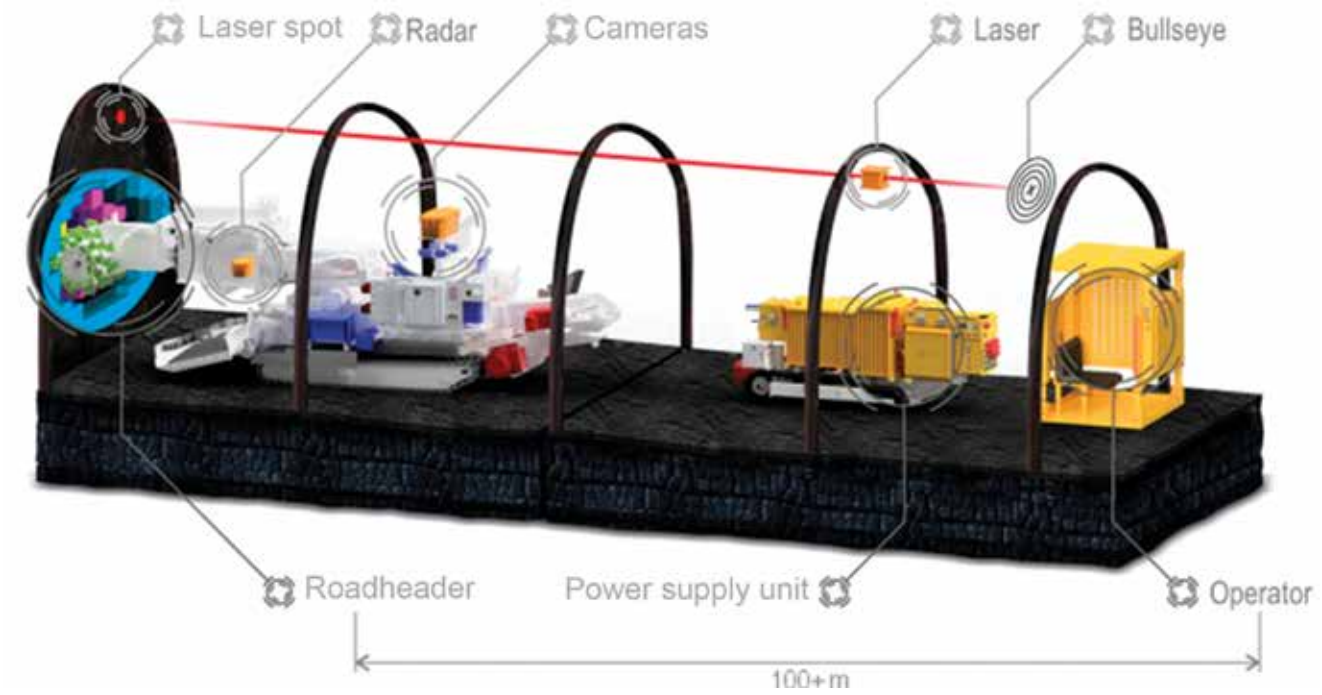

Figure 5: Structure of the EH-RemoteHeadControl v2 system by Elgór + Hansen[8].

The operator's station is equipped with computers presenting diagnostic information and the image from the cameras installed on the shearer as well as visualizing the operation of the machine. The real-time graphic representation of the cutting head makes it easier for the operator to drill the right profile. Audio and video are transmitted from three cameras located in the shearer's surroundings. This allows the operator to better understand the current conditions of the machine. The laser is installed in the excavation every 100 m and gives a beam of light in two directions. The laser is set using a wireless remote control and/or PC application.

The data recorded by the laser sensor, radar sensor and cameras allow the visualization station to determine the position of the shearer and the head. It also checks the possibility of their movement on an ongoing basis and determining a possible collision. The 3D application additionally maps the state of cutting in the face. It uses various indicators and lights and provides information on the shearer's condition, including the signalling of warnings and emergencies (**Figure 6**). Data transmission to the surface of the mine enables generating reports on the operation of the system.

3. RESEARCH AND DEVELOPMENT IN THE FIELD OF ROBOTIZATION OF MINING IN POLAND

Research centres in Poland are engaged in works in the field of mining robotization, which concern not only traditional mining, but also space and underwater mining. The effects of these works have, in most cases, been tested in underground mine conditions, and some of them have already been implemented.

3.1 Autonomous Machine for Breaking Rocks

The most important elements of the ore mining process have been presented earlier. In this process, the mined rock

Figure 6: 3D application of the EH-RemoteHeadControl v2 system by Elgór + Hansen.

from the face is transported to the surface. The transport system includes non-continuous haulage to handling points, also referred to as transfer points, where the mined rock is loaded onto conveyor belts. Large lumps of mined rock can damage the conveyor, so the handling points are fitted with grates mounted by means of manipulators with hydraulic hammers. The operator manipulates the boom to clear the grate of mined rock in the quickest possible way. The operator is exposed to many adverse factors. First, a hammer remote control followed by an autonomous machine were developed and installed. The project was implemented by the consortium composed of KGHM ZANAM S.A., AGH University of Science and Technology and KGHM CUPRUM Sp. z o. o. (Wroclaw, Poland). Research and Development Centre[14,15,16]. The main goal of the project was to develop an automatic grate cleaning system.

Constructing an autonomous machine required equipping it with an automatic control system, which, based on information from a number of sensors, would react to changes in the environment and generate control signals in such a way that the main goal, i.e., the cleaning of the grate, could be achieved. The main element was a hydraulic boom with a hydraulic hammer attached at the end. The boom has 4 degrees of freedom. An analysis of the functioning of the existing manual system was carried out and consultations with future users of the transfer points were held. The conducted analyses enabled specifying the tasks to be performed by the machine. the most important restrictions and requirements formulated in the form of the following assumptions.

The control system should operate in an autonomous manner.

- The operator can take over control at any time and turn off the autonomous system.
- At least 80% of activities related to rock crushing will be performed by the machine automatically.
- The operator interfering with the situation on the grate 20% of the time.

Figure 7: Station for testing; (a) autonomous equipment; (b) operator's panel; (c) GUI (Graphical User Interface) view.

- The process of clearing the grate of mined rock will last up to several minutes.
- Constructional changes must be as small as possible in relation to the existing equipment.

The system is, among other things, equipped with hydraulic cylinder sensors and a mined rock heap scanner. The system was installed at the test stand at KGHM ZANAM S.A. (**Figure 7**).

The stand was designed and constructed in a manner enabling its use in the underground mines of KGHM Polska Miedź S.A. The device should be adapted to work in the following conditions:

- Relative humidity up to 95% at a temperature of up to + 40 °C
- Degree of corrosive aggressiveness – C according to PN-71/H-04651
- Maximum relative humidity at a temperature of + 25 °C or at lower temperatures with 100% steam condensation.

The remote-controlled stand is monitored by cameras. It has been equipped with optical barriers and signalling devices to supervise and ensure traffic safety in the vicinity of the grate. The automation system controls the boom by means of signals determined by the current state of the system and the setpoint. This system consists of a master control layer and a direct control layer. In the

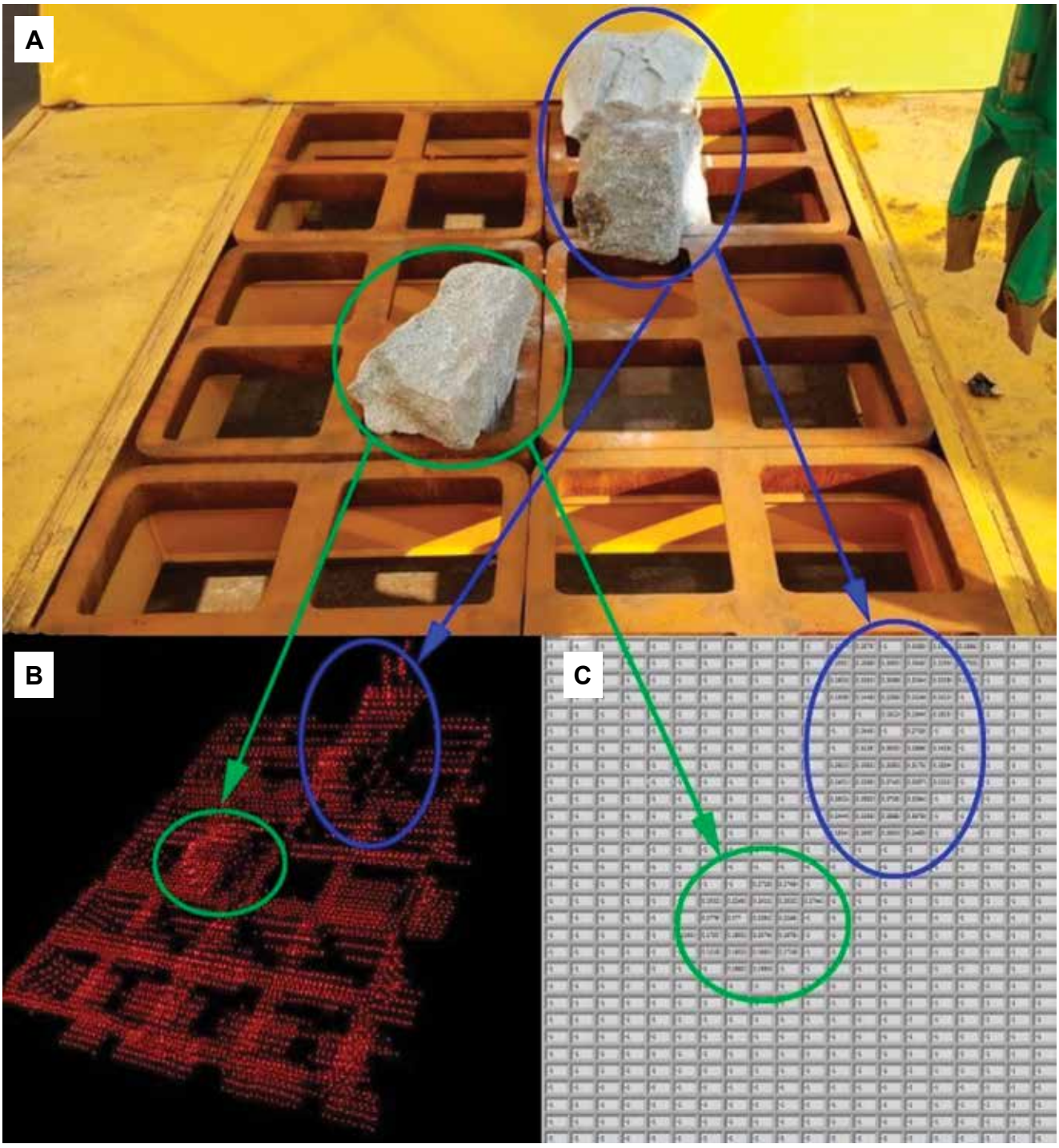

Figure 8: Analysis of the situation on the grate by the system: (a) view of mined rock on the grate; (b) view of the scan; (c) table of mined rock height on the grate[15].

superior layer, after identifying the shape and dimensions of the mined rock heap is identified (**Figure 8**). The control system generates a trajectory that will be implemented by the direct control system. The trajectory was developed using heuristic algorithms and observations of the grate cleaning process. The automatic control system consists of four main modules: mined rock identification, determination of hammer motion trajectory, inverse kinematics, and direct control. After being equipped with a shape identification assembly, the device becomes a robot, which autonomously detects the position of mined rock on the grate and then, starts removing it.

This autonomous robot system for breaking rocks performs tasks in accordance with the assumptions. The systems of mined rock identification, trajectory determination and implementation work well. Research has shown that the system can clear the grate of large chunks of mined rock in a satisfactory manner[15]. The next step was to mount the system on a real grate in a mine. The works were completed successfully.

3.2 Research Projects and Prototype Solutions

Below we present some examples of projects and solutions that significantly contribute to increasing the level of mining robotization and pave the way for the future mine, which is to be fully robotic.

An interesting project has been implemented by the Space Research Centre of the Polish Academy of Sciences and the AGH University of Science and Technology – "Development of a model of an automatic core drilling rig for work in extreme conditions, in particular in the space environment." The aim of the project is to design, construct and test a model of an automatic core drilling rig, the task of which is the unmanned sampling of material from a depth of several meters. The expected operating environments of the machine are both hard-to-reach places on Earth as well as the surface of planets and asteroids. Specific requirements are related to available power and mass. In addition, work under vacuum causes difficulty. However, it can fill the market niche, especially in the context of Poland's accession to the European Space Agency[17].

Another interesting example of a project is the automation of the shaft support control and monitoring system. This solution was developed by the Central Mining Institute. The laser system of automatic geometry measurement has been tested in terms of the recording, visualization and signalling of emergencies. This system increases the operational safety of shaft equipment and allows for continuous supervision at lower costs than periodically performed classic geodetic measurements[18].

In the introduction, attention is drawn to threats occurring in underground mines, which are the main reason for interest in the robotics of mining works. However, the problem does not only concern regular, typical mining works, but also rescue operations. Robots equipped with sensors for measuring concentrations of dangerous gases and climatic conditions should also participate in rescue operations. Robots provide reconnaissance for rescue teams giving them advance information on the conditions prevailing in the excavation. Therefore, robots should ensure the greater safety of people. This necessity is recognized all over the world, as evidenced by the multitude of construction solutions of mining robots from various countries. Groundhog, Wolvarine V-2, Gemini-Scout robots developed in the US, Numbat and the Water Corporation robots constructed in Australia, or Telerescuer, implemented by an international consortium, are examples of some robots. Tangshan Kaicheng Electronic from China offers robots for the hard coal mining industry. As part of the project "Research and feasibility study of a model of the M1 category mobile inspection platform with electric drives for potentially explosive areas", implemented by the consortium of the Institute of Innovative Techniques EMAG and the Industrial Institute of Automation and Measurements PIAP, the Mobile Inspection Platform (MPI) was developed. The most important functionality of MPI is to measure the concentration and climate parameters of the mine atmosphere on a continuous basis or at the request of the operator. MPI also sends the measurement results to the control and measurement console. The measurement results are archived together with images from cameras operating in the visible and infrared band.

The MPI's place of operation is a potentially explosive zone. So, since the very beginning, the robot has been intended to work as a machine that meets the requirements of Directive 94/9/EC (ATEX), as well as the Machinery Directive 2006/42/EC (MD) and Directive 2004/108/EC(EMC). The robot has been designed to overcome various obstacles, such as debris, water, mud and mining floor railways[19]. The above-mentioned units have also developed the Mining Mobile Inspection Robot (GMRI)[20]. **Figure 9** shows both MPI and GMRI mining inspection robots. These solutions are the first step for robots that will not only be able to reach casualties, but will also carry out basic activities related to the protection and removal of people from endangered areas.

4. ACTIVITIES PROMOTING ROBOTIZATION IN MINING

Poland is actively engaged in the development of robotization in underground and surface mining as well as in solutions for underwater and space mining. In addition to the three selected initiatives described in Section 4.1, Section 4.2 and Section 4.3, meetings, symposia and conferences are organized in Poland. An important direction of the development of robotization is also the Polish consortium, EX-PL, as well as the Centre for Space Studies of the Kozminski University.

4.1 euRobotics Topic Group on Mining

The well-known European association euRobotics has over 250 members. The aim of euRobotics is to increase European research, development and innovations in the field of robotics. euRobotics also supports its positive perception. The AGH University of Science and Technology leads the "Mining" group, one of 30 thematic groups in euRobotics. Thematic groups develop the content of the Strategic Research Agenda (SRA) and Multi-Annual Roadmap (MAR). Both SRA and MAR distributed by SPARC connects euRobotics with the European Commission in a public-private partnership. The SPARC partnership is the world's largest publicly funded robotics innovation program. Thematic groups (TG) identify the current challenges of their domain and describe the required progress in the capabilities of robots needed to meet these challenges. By connecting research, industry and end-users, TG can provide knowledge about the potential effects of robotics progress and enable knowledge transfer among the shareholders.

Figure 9: Mining inspection robots: (a) MPI[19], (b) GMRI[20].

In 2014, AGH University of Science and Technology in Cracow took the initiative to create a new working group in the structures of the euRobotics association, in the field of mining (Robotics in Mining). The idea of this project was conceived during the First International MARG Conference. (MARG stands for Mechanizacja, Automatyzacja i Robotyzacja w Górnictwie). In March 2015, during the European Robotics Forum, TG Mining was officially appointed. The AGH University of Science and Technology in Cracow became its coordinator. A series of meetings for potential new members of the association and new members of TG Mining were organized in the first year. As a result of this activity, AGH in Cracow, as the coordinator, defined the Multi Annual Roadmap for mining for the coming years, which was submitted to the euRobotics association and, next, to the European Commission. In subsequent years, TG Mining members took part in conferences and forums organized in various places in Europe. Several European Robotics Forums (ERF) have taken place – ERF 2016 in Ljubljana, ERF 2017 in Edinburgh, ERF 2018 in Tamper and ERF 2019 in Bucharest. During ERF 2017, in some of these meetings, participants discussed the possibility of initiating cooperation between TG Mining and Construction Robotics, Nuclear Inspection, Inspection and Maintenance or Oil and Gas groups. However, this year's ERF 2020 meeting took place in March, in Malaga[21,22,23].

4.2 Space Mining Conference

In the middle of 2016, a team consisting of students and academic teachers enthusiastic about space exploration focused on the space industry. All its aspects related to mining were established at the AGH University of Science and Technology. Ideas for Space Mining Engineering (ISME) was created to prepare and conduct the Space Mining Conference organized by the AGH University of Science and Technology in Cracow. The first Student Space Mining Conference 2018 was a significant success and an important event. ISME organized a second conference in 2019. A third conference is being planned for 2020. The ISME Group (Krakow, Poland) covers all aspects (technological, mechanical, economic, legal and ethical) related to space exploration, including extra-terrestrial resource use. This initiative has attracted an increasing number of participants and listeners. Analyzing the speeches of the participants of these conferences, one can notice a great emphasis on the problems of automation and robotization of mining works as the only possibility of space exploitation. Although the topic is relatively new, it is rapidly developing. Current information can be found on the Conference website[24].

4.3 PERASPER Research Cluster

The PERASPERA project (in Latin "Per aspera ad astra" means "Through hardships to the stars"), created in 2014, is financed by the European Union under the Horizon 2020 program. The goal of the PERASPERA initiative is to support industry competence in Europe. The focus is planetary and orbital robotics, and to demonstrate key technologies related to these fields in space. In 2019, Poland joined the PERASPER Research Cluster. Poland's membership in the consortium may facilitate the participation of domestic space sector entities in innovative space projects and cooperation with large European entities, as well as the testing of technologies in the field of orbital and planetary robotics in space. Polish companies, institutes and universities have extensive experience in the field of ground robotics and implemented projects related to space robotics systems. The field of space robotics in which Poles have the widest competence is underground exploration. This exploration includes devices for sampling, mechanisms working in vacuums, devices for underground testing as well as systems and control sensors. Experience and potential in the production of subsystems and components for orbit robotics systems are also evident in Poland. Servicing objects in orbit can be accomplished because of expertise in Poland with gripping and holding mechanisms, control systems, connectors, motion sensors and antenna systems[25].

CONCLUSIONS

The underground mining industry has difficult conditions and high costs of implementation. The development of new technical measures is exposed to high risk in terms of both technical and financial capabilities of the contractor. Research and development (R&D) entail the necessity to carry out basic tests in the first phase, including design works. The second phase of R&D involves carrying out field tests and implementing new machinery and equipment solutions. These tests need to be carried out under specific mining, geological, technical, and organizational conditions. Tests must also comply with the regulations of the State Mining Authority (Poland)[26]. The existing

solutions that have been used for many years in various industries cannot be easily transferred to underground mines. Robotic vehicles are currently able to respond to typical road situations, including pedestrians, traffic lights and traffic control by a police officer. However, underground loaders or dump trucks still do not have such autonomy. Moreover, typical anthropomorphic robotic solutions work well in the production process. These solutions include the implementation of assembly or welding processes, while the process of installing support arches in underground excavations has only been mechanized.

In mining, especially underground, the simplest solutions are the best. Difficult conditions and high costs sometimes limit the use of technical means to the necessary minimum. However, automation and robotization in mining are developing slowly and encounter many obstacles. Some solutions have already been implemented in mining practice. Solutions include systems supporting the work of self-propelled drilling carts and roadheaders, an autonomous machine for breaking rocks, automated longwall systems, and rescue works. The effects of implementing these solutions are tangible. The presented solutions make it possible to work in severe environment and conditions. People are not able to operate in these environments and conditions. For more specific effects, more research and analyses need to be conducted.

Poland has many underground mining plants and producers of mining machinery and equipment. Poland is good training ground for the development and testing of automated as well as robotic machines and machine systems. The establishment of TG Mining (part of euRobotics, a rapidly growing ISME group) organize space mining conferences. Other initiatives in Poland, like consortium EX-PL and the Centre for Space Studies of the Kozminski University, PERASPERA are also important for robotization.

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Bigger is not always better

When operators are experiencing problems with their conveyor belts, or even when they simply want to increase their operational lifetime, increasing the belt specification is often seen as the best way to solving the problem. More often than not, 'going bigger' by increasing the tensile strength, the number of plies or the thickness of the covers, has the opposite effect and actually makes matters even worse. Here, Dunlop Conveyor Belting's head of application engineering, Rob van Oijen, explains why bigger is not always better.

IDENTIFYING THE TRUE CAUSE

The majority of problems involving rubber conveyor belts seem to have quite an obvious cause. As a result, the solution appears to be equally as obvious. But if the diagnosis of the cause is incorrect then so will be the solution. The most common example of this is rapid wear of the covers of the belt, especially the top cover because proportionately it wears four times faster than the bottom cover. The most obvious cause of rapid wear would logically be the abrasive nature of the materials being conveyed, which is true up to a point. To improve belt life the logical answer would therefore seem to increase the thickness of the covers. However, experience proves that this is rarely the best course of action.

QUALITY NOT QUANTITY

Without a shadow of a doubt, the biggest single cause of rapid belt cover wear is due to the rubber having insufficient resistance to wear. In other words, the rubber compound used by the manufacturer has not been engineered to provide the level of wear resistance needed for the job. It is important to bear in mind at this stage that when comparing abrasion test results, higher figures represent a greater loss of surface rubber, which means that there is a lower resistance to abrasion. Conversely, the lower the figure the better the wear resistance.

The manufacturer may claim that the rubber meets DIN Y (ISO 14890 L) standards for abrasion resistance (maximum volume loss in cubic millimeters of 150 mm^3 under ISO 4649 / DIN 53516 test methods). However, in reality, the wear resistance may only be borderline at best or, as we regularly find during laboratory testing, have totally inadequate resistance. One example we found only recently was a steelcord belt with an abrasion resistance of 264 mm^3. Not only is that more than 50% higher than the maximum level for DIN Y compliance, the manufacturer had sold the belt as being a *DIN W specification*, which demands a maximum of 90 mm^3, so the belt actually had an abrasion resistance level that was more than three times less than it should have been.

NOT JUST ABRASION

As mentioned previously, the most logical solution to rapid wear would seem to be to install a belt with even thicker cover rubber. Thicker covers will certainly endure more wear but on the downside, the added weight will increase the absorbed motor power of the system. Over the whole lifetime of the belt, this can amount to significant added cost. It is also important to bear in mind that the ability of a belt cover to withstand wear is not due to its 'abrasion resistance' alone. The resistance to wear of the rubber is a combination of its overall strength, its resistance to

abrasion and its resistance to tear propagation. If the latter is very low then a small, seemingly insignificant area of damage in the extra thick cover can easily increase due to the continuous material loading and the relentless flexing of the rubber around the drums and pulleys. In time, this damage will connect to another area of damage and consequently a small piece of rubber will effectively be cut out and lost rather than simply worn off. In reality, although doubling the cover thickness will add some lifetime it will certainly not double the lifetime of the belt. Invariably, the only real solution lies with improved quality rather than increased quantity and only buying belts where you are confident of their provenance (manufacturer's origin) and where the manufacturer clearly states the level of anticipated performance rather than simply claiming to be of a certain DIN or ISO standard.

INCREASING THE TENSILE STRENGTH

When problems are being caused by impact damage and/or ripping and tearing, there is often the temptation to fit a belt with a higher tensile strength and/or a belt with an increased number of plies. The same 'solution' is often tried when there are problems such as too much elongation (stretch), repeated splice failure or where mechanical fastener retention is poor. To be fair, increasing the tensile strength is worthwhile if the current belt damage is due to a too little load support, provided that the design of the conveyor allows it. The same applies to belts that are obviously under-specified in the first place.

THE NEGATIVE EFFECTS OF INCREASING THE TENSILE STRENGTH

Simply increasing the tensile strength or the number of plies can cause more problems than it solves. First of all, the belt becomes heavier and less flexible in both length and width. Reduced longitudinal flexibility usually necessitates an increase in the diameter of the drive pulley. Increasing tensile strength by just one step usually means an increase in diameter of 25% or more. Failure to increase the pulley (drum) diameter can lead to dynamic stress failure, especially in splice areas. Reduced horizontal flexibility causes a decrease in troughability. Last but not least, and as mentioned with increasing the thickness of the covers, there is also a price to pay in terms of increased power consumption, which can be quite marked.

TEST IT FIRST

In all cases, before any change of belt is considered, I would strongly advise getting a completely new belt calculation using a professional belt calculation program. And if you have a piece of spare belt available then it is often a good idea to send a square meter of it for laboratory testing to measure its true tensile strength. There are two reasons why this is advisable. In belts that have low quality (low cost) fabrics, it is unusual to find a fabric that has inadequate tensile strength. However, although the amount of material used in the longitudinal strands of the fabric may be adequate, the amount of transversal weft material is often kept to an absolute minimum in order to reduce cost. Although the required tensile strength might be achieved, rip and tear resistance is reduced and elongation (stretch) is low. Low elongation may sound good in principle but if the elongation is too low then this can cause problems

Not what they seem – The use of totally polyester (EE) plies rather than a combination of polyester and nylon.

with transition distances and a general inability to accommodate the contours of the conveyor and its drums and pulleys. Ultimately, this can lead to the premature failure of the belt.

NOT WHAT THEY SEEM

The second reason for checking the true tensile strength of a belt before replacing it is that it is becoming increasingly common for some manufacturers, traders and importers to supply belts that have totally polyester (EE) fabric plies in a carcass that is declared as being an EP (polyester/nylon mix) carcass construction. The simple reason for this deception is that EE fabric costs some 30% less than EP fabric. In itself, this may not seem like a great deal but the fabric plies are a major cost component in any multiple ply conveyor belt so using the much cheaper polyester fabric is a big help when trying to achieve the perception of a lower 'like for like' price. The whole basis of using a mix of polyester and nylon fabric is that it has the best balance of mechanical properties including allowing a conveyor belt to run straight and true, to trough, to flex round pulleys and drums, stretch, transversal rigidity, longitudinal strength and much more besides.

The use of totally polyester (EE) fabric compromises a whole range of essential mechanical properties. The biggest danger is that a polyester weft can cause low transverse elasticity, which reduces both the troughability and impact resistance of the belt and also causes tracking issues. In addition, less weft in the belt can also reduce rip resistance, fastener strength and ability to handle small pulley sizes. The seriousness of the detrimental physical effects for the end-user are therefore huge. One test that I witnessed recently revealed that the tensile strength of the carcass was more than 20% lower than the specified minimum. To sum up, simply replacing a belt with one with a specified higher tensile strength and/or an increased number of plies is most often merely compensation for poor quality rather than a genuine and honest lack of (tensile) strength.

As with the solution to premature surface wear, the real solution lies with only buying belts where you are as sure as you possibly can be of the quality, the provenance and the integrity of the supplier. Bigger is certainly not always better.

ABOUT THE AUTHOR

Rob van Oijen is Manager Application Engineering for Dunlop Conveyor Belting in The Netherlands is one of the most highly respected application engineers in the industry. He has specialized in conveyors for over 14 years, supporting businesses throughout Europe, Africa, the Middle East and South America.

Mine water under pressure

The deeper the pit, the more difficult it is to dewater: when normal pumps reach their capacity limit, they only continue in sev-eral stages.

The race for scarce raw materials is in full swing worldwide. Deposits that were inaccessible or economically unattractive just a few years ago have long since been developed. Infrastructure projects are also becoming increasingly ambitious, as the Gotthard base tunnel shows. This poses ever greater challenges for water management.

Many distances can often no longer be covered with the usual sub-mersible motor pumps. Above all, the distances to be bridged verti-cally are decisive. Most pumps are in a performance range of only 10 to 40 metres. But even these values are relative: In practice, they only raise a small part of the specified maximum flow rate to this height. This is because height and volume interact with each other. The higher, the less water passes through.

Connecting pumps in series

Some operators therefore use a series connection: two pumps are operated in series in the same line. This roughly doubles the achiev-able line capacity. However, the flow rate remains the same. Usually, hose lines are used between the units. However, this concept carries the core risk of all complex systems: (Too) many components are in-volved, these may not be in top condition, may not be optimally set up or simply should not have been combined at all.

A process advantage here is offered by an adapter from the product world of the pump manufacturer Tsurumi, with which two identical pumps can be coupled directly with each other. The result is virtually a super pump. Nevertheless: The physics of speed and impeller is the limiting factor, which is why the pump programme of most manu-facturers ends at this point.

If there is no longer enough for dewatering, tunnel or quarry opera-tors will have to make do. In contrast to clear water, there are only a few pumps in the dirty water sector that achieve significant additional performance.

Multistage pumps

High-pressure pumps are then the means of choice. The LH series from Tsurumi, for example, bridges the range from 42 to over 100 m delivery head. However, the classic design has already reached its physical upper limit.

If you want to go even higher, a different pump design is required. In this case, multistage pumps are used. Technologically, this means that several impellers are mounted one behind the other in the cas-ing. Although the flow rate remains the same here, the delivery head increases with the number of these stages: The pump delivers more pressure and can therefore handle a larger water column. The idea is as simple as it is difficult to implement when it comes to water con-taining solid components.

Tsurumi from Japan is the only supplier of such dirt water pumps in the world. In the delivery programme they are marked with a "W" in the model name. The LH4110W is the top model. It is capable of pumping muddy water vertically upwards from a level of 216 m. For comparison: This even exceeds twice the height of London´s Big Ben tower. The unit moves water with a speed up to 400 l/min. If the re-quirements are reduced, for example to a delivery height of 170 metres, the delivery rate increases fivefold to 2000 l/min. The power for this is generated by a motor with 110 kW power consumption. If two of these 1825 x 616 mm large monsters with a dry weight of 1270 kg were to be connected in series, a 432 m deep pit would be supplied with the least amount of effort.

Extreme: Mega pumps in series

Even in the enormous high-pressure pumps, you can find what has already made the manufacturer the world leader in the construction pump market with conventional pumps: Ultra-hard materials, clever cooling, forced lubrication that is safe to run dry, individually encap-sulated conductors. "Stronger for longer" is the slogan of the Japa-nese, who only 35 years ago opened their European headquarters. Customers do not have to wait long: While customary in the industry it takes weeks to months to produce to order, the Japanese deliver a large part of their product range within 24 hours thanks to huge cent-ral warehouses.

Multi-stage dirt water pumps are not only the technical ultimate, but also, due to the lack of real alternatives, are considered the ultimate solution for users with high performance requirements who want to make their water management as compact and fail-safe as possible.

The All New MAXAM Mining Haulage Tire – MS412

MAXAM Continues to Innovate Solutions for Open Pit Mining Applications.

Gaining a strong reputation in the industry, MAXAM Mining Group continues to innovate, adding the all-new MS412 27.00R49 to their open pit mining, quarry and OTR program. Designed to meet the demanding conditions in mine sites globally, the MS412 is the result of cutting-edge engineering and groundbreaking compounding technology.

The MS412 features a high net-to-gross tread pattern that provides extremely low wear rates that drastically increase tire life. MAXAM's engineers have also strategically placed stone ejectors to provide maximum protection from stone drilling, which leads to the cause of premature tire removal and out of service conditions. Engineered with tread grooves that allow for exceptional traction and heat dissipation, the MS412 delivers excellent traction in a variety of haul roads conditions. To enable high speed operation with minimum heat build-up, MAXAM has optimized the MS412's base compound to help maximize productivity for mining operations globally.

Featuring a strong all-steel casing to reduce cuts and punctures, the all-new MS412 is engineered with increased casing durability to dominate severe hauling conditions. As an innovative group, with years of expertise in the mining industry, MAXAM's engineering team has designed the MS412 with a high lug-to-void ratio for improved wear and impact protection, providing mine sites increased protection and wear on haulage tires. Similar to all large mining haulage tires in MAXAM's program, the MS412 has deep tread grooves to provide cooler running tread and longer tire life.

Delivering a premium E4 haulage tire to the industry, the MAXAM MS412 provides exceptional performance, minimum cost-per-hour and a high net-to-gross pattern for maximum tread wear. The MS412 is available in one size as noted in the below chart. Available in multiple tread compounds, including the ultra-cut resistant compound, recently released and innovated by MAXAM's engineering and R&D team, the MS412 is a rugged solution that maximizes the haulage truck's resilience in the toughest mining environment.

For more information, please contact your local representative or visit us at www.maxamtire.com.

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ABEL Pump for the transfer of thickener concentrates

One of ABEL's customers is a Latin American mining company active in copper mining. Even on an international level, the company is a large copper producer.

The company cares for its environment, given that it also represents its main source of resources and revenues. Consequently, business development is carried out with a strong sense of community and care for the environment. All efforts are concentrated on the optimization of process efficiency and on maintaining or reducing associated costs at the same time.

The media

A mineral product is generated from the underflow from the thickener with a solid content ranging between 58% and 72% by weight. This slurry constitutes an abrasive material which is difficult to handle and to pump.

Due to these properties, the equipment used for transferring these materials acquires a high level of wear, unexpected downtimes, unscheduled maintenance etc.. These are costs that the mining industry cannot accept.

Taking these circumstances into account, the best solutions possible have been analysed to fulfil this critical task.

The application

In this context, it is essential to study and identify the most suitable equipment to satisfy the requirement of the application in terms of availability, efficiency and operating expenses.

Originally, 2 centrifugal pumps were installed in an unconventional way to perform the required task. Centrifugal pumps are designed for specific conditions which generally never occur given that the operating flow and the solid content of the materials being transferred vary during operation due to pressure fluctuations in other phases of the process. In such circumstances, this type of technology sees its performance dramatically reduced, which directly impacts the pumps' output, causes product recirculation and frequent downtime of the related production line.

Under such circumstances, our customer was obliged to look for a solution that would immediately tackle the challenges and resolve the problems of this specific application.

The solution

When it comes to mining applications, the equipment installed must guarantee a high degree of reliability and availability, it must also be suited to being operated in challenging conditions and during long periods without interruptions.

ABEL HM hydraulic diaphragm pumps in very challenging work conditions.

The equipment installed uses piston-diaphragm pump technology and therefore it can be operated for 1 year under the described conditions without requiring any preventive or corrective maintenance.

Main characteristics

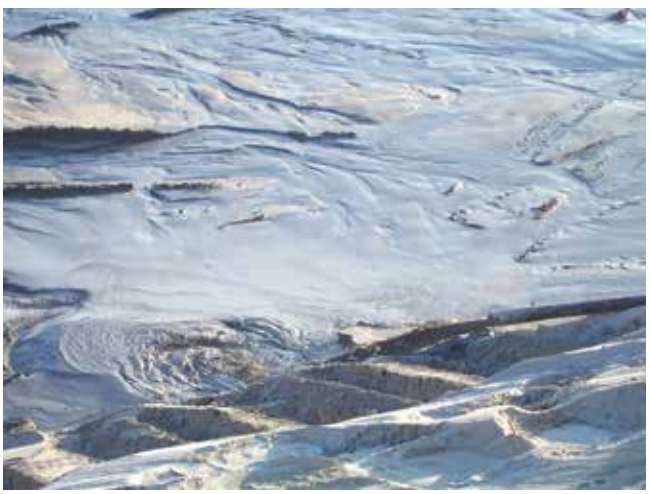
Performance range: up to 100 m3/h and up to 10,0 MPa

Advantages

- Transfer of media with a solid content of up to 75%.
- Extra-large suction valves for a high degree of volumetric efficiency.
- Pre-formed diaphragm which improves pumping efficiency, durability and availability of the equipment.
- Constant operating flow, independent from the discharge pressure, which is mainly influenced by fluctuations of solid contents.
- Strokes per minute are low and ensure a low mechanic wear.

Thanks to these properties and design, the pumping equipment offers a long useful life and satisfies the requirements and the needs of the mining industry perfectly.

The pressure ranges handled by the pumps of the HM series provide for an optimum process design. HM pumps contribute to the success of the mining plant with significantly lower pumping costs thanks to the very low maintenance required, lower electric energy consumptions and high levels of availability.



Copper Tailings

Water cannon joins list of remote operating machines

Newcrest Mining's Cadia Valley Operations has achieved a world first in mobile equipment interoperability - integrating a remote operated MacLean water cannon into its Epiroc automation fleet at Cadia East.

In 2018, Cadia commenced a loader automation trial with mining equipment manufacturer, Epiroc, with the aim of removing operators from the Cadia East underground environment, while maintaining productivity and performance.

The loader trial proved successful and the next phase involved integrating non-Epiroc machinery into the existing automation fleet.

Cadia's Mining Innovation & Automation team worked with Epiroc and MacLean to seamlessly integrate a MacLean water cannon capable of localisation with Epiroc's traffic management system and safety hardware, so that it could be introduced into the automation safety system.

Water cannons are used for secondary break operations, using high pressure water to release wedged rocks in underground drawpoints.

By integrating the MacLean IQ Series tele-operation system with Cadia's automation safety system, the water cannon could be safely operated from the surface in a tele-remote capacity, allowing it to work alongside Cadia's semi-automated loaders.

The water cannon was trialled and commissioned during July and August and is now in use at Cadia East.

Cadia General Manager, Aaron Brannigan said that integrating the water cannon into Cadia's automation system has improved the efficiency of the production level and removed human exposure from drawpoints.

"We are constantly pushing the envelope of change in the innovation and technology space. Automated machinery allows for shift in technical capabilities of our workforce, while ensuring we continue to eliminate safety risks from our operation," Aaron said.

The success of this milestone paves the way for further integration of other key pieces of secondary break equipment into the automation system.

This project is part of Newcrest's ongoing drive to increase its automation and innovation focus on site.

Komatsu introduces new and redesigned LHDs for hard rock mining

With a whole new chassis, powertrain and operator cabin, Komatsu's brand-new WX07 7-tonne LHD has been designed from the ground up to provide a standout experience and environment for underground hard rock mining operators.

Compared to competitors in its size class, the WX07 is 15% faster on a grade and delivers up to 10%bmore breakout force, making it up to 14% more productive. Engineered for small and narrow vein mines, this machine offers a combination of Z-link kinematics, a reinforced boom and efficient bucket design that enables excellent penetration into the pile for fast bucket filling. The WX07 is engineered to keep minerals loading with a 243-liter fuel tank for longer operational cycles between refuelings.

The WX07's operator cabin is built for visibility and ergonomics, including ample headroom for ease of entry and exit. A design that makes vital maintenance components accessible from ground level means that crews can perform service and repairs without the need to climb or use a ladder to get to key areas.

In addition to the new WX07, Komatsu's popular Joy 4LD has been redesigned, renamed the WX04 and rebranded as a Komatsu product. A 4-tonne LHD built for challenging narrow vein applications, the WX04's 190-liter fuel tank offers 31% more capacity than its closest competitor, based on published data. The WX04 also offers 20% more breakout force than any machine in its size class.

"We're excited to add the WX07 and WX04 to our LHD lineup, which now has a capacity that spans from 3 to 22 tons," said Bill Maki, product manager for Komatsu's LHDs. "No matter what class of LHD your operation needs, Komatsu offers a choice of machines to consistently haul your ore efficiently and effectively."

The WX07 and WX04 are both available for order immediately. For more information, contact a Komatsu distributor or visit mining.komatsu.

New Stronger ElectroMax-Plus Overband Magnet

The design objective of creating a more compact and powerful electromagnetic Overband Magnet led the Bunting engineering team to develop the new ElectroMax-Plus.

Bunting is one of the world's leading designers and manufacturers of magnetic separators, eddy current separators and electrostatic separators for the recycling and waste industries. The Bunting European manufacturing and product testing facilities are in Redditch, just outside Birmingham, and Berkhamsted, both in the United Kingdom.

Electromagnetic Overband Magnets use an oil-cooled or air-cooled wire coil to generate a deep and strong magnetic field. The electromagnetic force radiates from a coil wound around a steel core and mounted inside a steel box with a thick steel back-bar. This focuses the magnetic field in one direction: down towards the conveyed material. In operation, an Overband Magnet, suspended over conveyors, screens, and vibratory feeders, lifts and removes ferrous metals such as iron rebar and beverage steel cans.

Overband Magnets are a common feature on many mobile screens and crushers. In such applications, minimising weight and size is crucial and, subsequently, operators use standard Ceramic Ferrite or, less frequently, Neodymium Rare Earth Permanent Overband Magnets rather than Electromagnets. Neodymium Permanent Overband Magnets produce a strong but shallow magnetic force and often experience problems with belt and motor damage due to large ferrous metal clamping against the magnet block. The magnetic field of the light and compact ElectroMax-Plus is both deep and strong, enabling excellent separation performance at higher suspension heights. In addition, simply turning off the electromagnet releases any extremely large entrapped tramp ferrous metal. The shape and nature of this magnetic field means there is less wear to the self-cleaning belt mechanism (e.g. belt, motor gearbox, and bearings).

Figure 1: Bunting's ElectroMax-Plus Overband Magnet

The new ElectroMax-Plus operates at a 600mm suspension height (the distance between the conveyor belt and the face of the Overband Magnet), up from 450mm on a standard ElectroMax. At a suspension height of 500mm, the ElectroMax-Plus is over 105% stronger (in terms of Force Index) that the equivalent ElectroMax. This incredible additional magnetic force removes small tramp ferrous metal commonly missed by permanent Overband Magnets.

The latest ElectroMax-Plus provides companies in the recycling, quarrying, and mining sectors with a powerful and compact solution for separating tramp and secondary ferrous metal from conveyors.

"Companies supplying mobile recycling equipment are requesting stronger and lighter Overband Magnets," explained Adrian Coleman, the General Manager of Bunting's Redditch operation. "The new ElectroMax-Plus provides a real alternative to Neodymium Rare Earth Overband Magnets. There is the requested additional magnetic strength, without the operating problems (as experienced with some Neodymium Rare Earth Overband Magnets).'

The new ElectroMax-Plus extends Bunting's comprehensive range of Overband and Suspension Magnets. In additional to standard sizes, Bunting also designs and manufacturers bespoke models which are application specific.

Additional information on metal recovery and separation using the ElectroMax-Plus Overband Magnet, ElectroStatic Separators, Magnetic Separators, and Eddy Current Separators is available on the Bunting website.

Bunting-Redditch website – www.mastermagnets.com

Figure 2: Bunting's ElectroMax-Plus Overband Magnet

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