

# MINING & QUARRY WORLD



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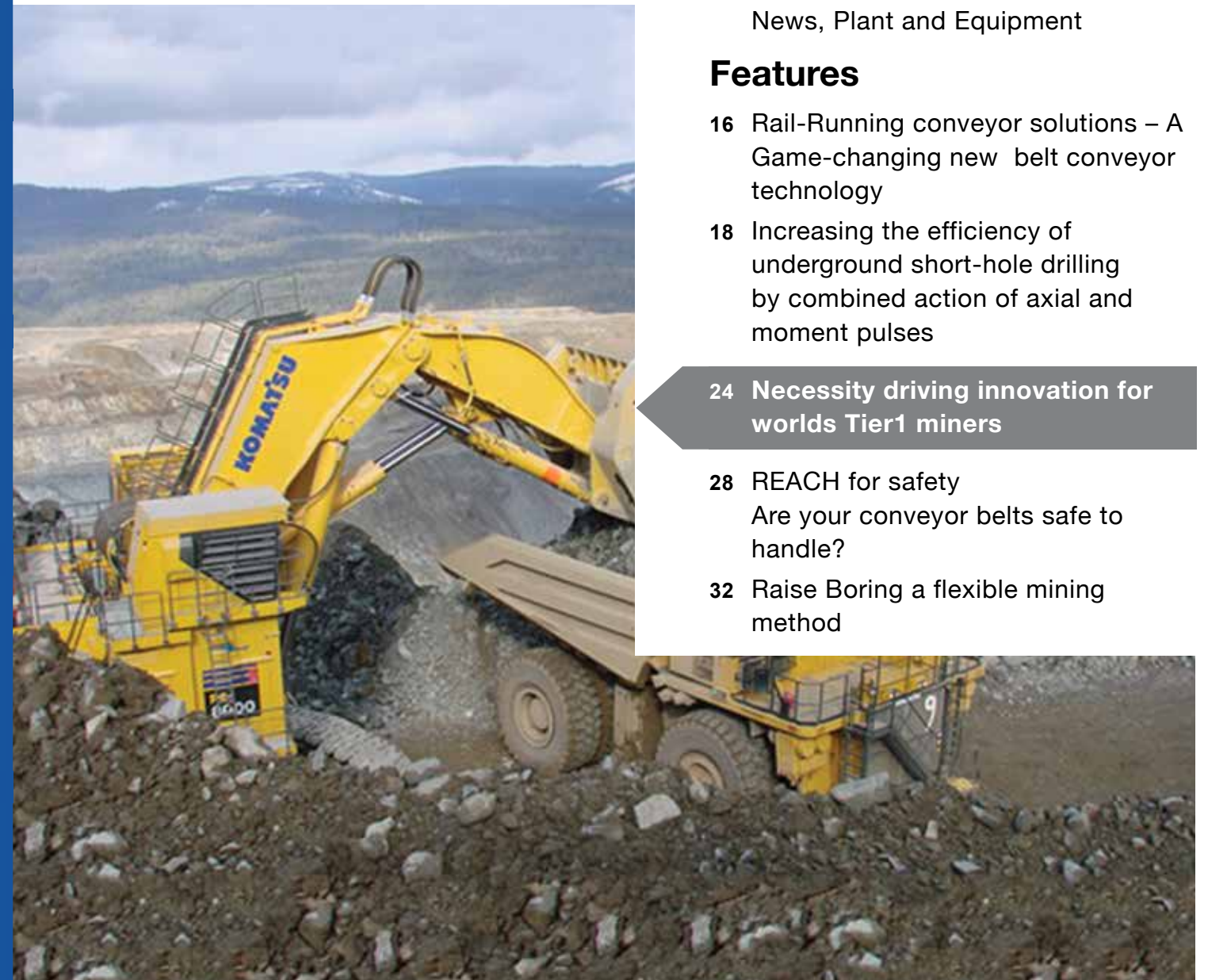




News, Plant and Equipment

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**Martin Engineering**

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**7 to 10 March 2022**  
 Metro Toronto Convention  
 Centre, Toronto, Canada



**26 to 28 April 2022**  
 Crocus Expo,  
 Moscow, Russia



**27 to 29 of April 2022**  
 Lima, Peru



**5 to 5 of April 2022**  
 Uzexpocentre, Tashkent,  
 Uzbekistan



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**7 to 10 June 2022**  
 Novokuznetsk, Russia



**October 2022 dates TBC**  
 Kolkata, West Bengal, India



**24 to 30 October 2022**  
 Munich, Germany



## Enhanced geoscience data supporting Canada's mining and metals industry

Natural Resources Minister Jonathan Wilkinson has endorsed the Pan-Canadian Geoscience Strategy, outlining Canada's intention to produce world-leading geoscience to improve the competitiveness of its mining and metals industry.

The strategy represents a renewed commitment to improving collaboration and the availability and accessibility of public geoscience data and knowledge.

Accessible geoscience data can help lower exploration costs, inform evidence-based land use decisions and support geohazard risks management and climate change mitigation.

The strategy identifies

five priority areas, which seek to increase the impact of geoscience by supporting robust science and data, developing skilled scientists, and growing exploration and collaboration, all of which will support Canada's critical minerals strategy that is currently under development.

"Canada has the resources and the expertise to lead the world in producing, processing and growing value chains for critical minerals. The Pan-Canadian Geoscience Strategy, codeveloped by federal, provincial and territorial geological survey organisations, will help propel the sector forward," commented Wilkinson.



## Scoping study under way for Big Sandy

Junior Arizona Lithium has launched a scoping study into its Big Sandy lithium project, in the US.

"The previously announced excellent metallurgical results demonstrate the significant potential of the Big Sandy lithium project and, with these results in hand, the company has appointed Arizona-based Ausenco Engineering to complete a scoping study.

This represents the

first step in the process of evaluating extraction, treatment and transportation options, identifying key cost centres that allow for evaluation and optimisation, thereby creating optimum value, while making the project a global model for responsible and sustainable mining," said Arizona MD Paul Lloyd.

"Given the large existing Joint Ore Reserves Committee-compliant lithium resource with excellent



## Cat fleet hits global autonomous milestone

"Congratulations to the Caterpillar team and our customers on reaching this impressive milestone," Caterpillar Resource Industries Group president Denise Johnson said.

"Having 500 driverless trucks in operation across the globe is tangible evidence of our ability to innovate and a clear indication of Caterpillar's commitment to the future of mining."

Cat's engineering teams look to the future when developing onboard technology, and partner with customers to ensure its products and services are tailored to achieve customers' specific business goals, as well as meet the industry's most pressing needs.

Caterpillar has been investing in autonomous development for decades. From 1994 to 1995, Caterpillar ran the first two prototype Cat 777C

autonomous mining trucks at a Texas limestone quarry, where they successfully hauled more than 5000 production loads over a 2.6-mile course.

Caterpillar has autonomous mine sites operating 24/7 on three separate continents, and at the end of 2021, customers using Cat Command technology had safely hauled more than four billion tonnes and travelled over 145 million kilometres autonomously.

Driverless trucks are safer and have up to 30% improved performance over those with operators.

By leveraging Cat's deep expertise, the company is breaking new ground in autonomous equipment for mining, quarry/aggregates, construction industries and beyond.

Cat uses leading-edge technology to help customers build a safer, more productive mine site.



## FLANDERS announced that it will deliver its ARDVARC Autonomous system to Codelco

Codelco is converting Radomiro Tomic mine to an automated drilling operation as part of a 3-year strategic project and the conversions of the first six drills are expected to start in early 2022.

For the project, US owned engineering company FLANDERS is expected to deliver an

automation system based on its ARDVARC Drill Control System.

The system enables Codelco to operate three EPIROC Pit Viper 351 electric drills in full automation mode and three SmartRoc drills in a semi-autonomous tele-remote operation.

FLANDERS' ARDVARC

product suite is designed to facilitate customers to scale up automation at their own pace and covers all aspects of drill automation, from semi-autonomous to tele-remote and autonomous operation of a single piece of equipment to multi-machine control and full-fleet automation using

Command Center control capabilities.

ARDVARC Autonomous comprises a suite of tools for automating, analysing

and optimizing drilling production and processes.

The autonomous drill system will integrate into the existing fleet management systems at the Radomiro Tomic site, and all drill data will be provided to Codelco for their own interpretation and use in downstream processes.

Lindor Quiroga, Managing Director of Codelco's R. Tomic mine, said, "we need to explore the automation of our mining equipment to continue our evolution, challenging our technical limits and eliminating the exposure of our personnel.



## Atrum keeping Alberta coal dream alive

Coal developer Atrum Coal is continuing its information drive for its Elan coal project, in Alberta.

The company was last year forced to pause a prefeasibility study for the Elan project after the government of Alberta took a decision to reinstate the previously rescinded Coal Development Policy for Alberta.

The policy dictates the condition for coal leasing, exploration and development, and prohibits future coal exploration approvals on particular land types.

Elan is located on land designated as Category 2 under the coal policy, referring to land not normally considered for open-pit coal mining, unless appropriate environmental stewardship is applied.

The company noted that fellow coal developer Benga Mining, which is hoping to develop the Grassy Mountain coal project, also in Alberta,

has hit a roadblock. That particular project was halted with the change in legislation, and Benga, along with two First Nations groups had applied for permission to appeal the provision component of the Joint Review Panel (JRP) decision, which had found that the project was not in the public's best interest.

The single appeal judge has now denied all three applications for permission to appeal, meaning the three parties would not be able to appeal the JRP decision. However, Benga and the two First Nations have also filed a judicial review challenge of the provincial component of the JRP decision with Alberta's Court of Queen's Bench.

The Grassy Mountain project holds a Category 4 land use classification, being land on which surface or underground mining may be considered, with nearly 25% of the project sitting on previously

mined land, which was mined over 60 years ago and never properly restored at the time, but will be restored if the project proceeds.

Atrum nonexecutive chairperson Glen Koropchuk said that the company would take all learning opportunities, including the decisions of the JRP on the Grassy Mountain project, to work with its own Indigenous and local community stakeholders in order to improve its Elan project environmentally and socio-economically.

Elan is expected

to require a capital investment of \$773-million.

An updated scoping study into the project increased the expected mine life of the Elan project from the 15 years considered in the previous scoping study, to 21 years, with total run-of-mine coal mined increasing from 126-million tonnes to 187-million tonnes.

Annual throughput rates have remained unchanged at 10-million tonnes a year, while total saleable hard coking coal product has increased from 76-million tonnes to 112-million tonnes.





## RPMGlobal releases major upgrade to XPAC Scheduling Suite

RPMGlobal (RPM) has released the latest version of its industry-leading scheduling software, XPAC Solutions.

The latest version is focused explicitly on significant features requested by and developed with XPAC Solutions users globally. Some of these notable features include disturbance reporting and scheduling, landform surface definition, support for battery trucks, multiple independent calendars, bi-directional Integration with RPM's Schedule Optimisation Tool (SOT) and many more commodity-specific enhancements.

According to Richard Mathews, RPM's Chief Executive Officer, this release of XPAC Solutions is the most significant in the past several years. "We committed a lot of resources to this release. Coming off the major investment we made in performance and usability in the previous release, we had a very solid platform to introduce these new industry-leading features, without comprising speed, quality or accuracy".

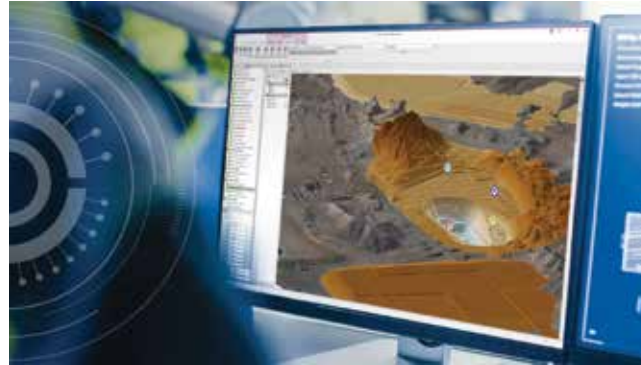
One of the most significant additions to the software suite is the environmental features allowing for disturbance reporting and scheduling with

enhanced spatial zoning. This is ideal for reporting areas that are disturbed by mining and dumping within key areas, such as water catchment and habitat of specific animal species and constraining those areas within the schedule.

Along the same vein of environmental enhancements is the addition of battery electric truck modelling. This latest release provides full support for battery trucks including the ability to define which road segments can be used to recharge batteries. Therefore, users can evaluate whether adequate recharge provision has been made throughout the schedule by providing net energy usage information.

The addition of multiple independent calendars will also appeal to many users of the solutions. Schedule and Product Optimiser (PO) can now use different calendars, including those with variable period durations. This provides enormous flexibility and further strengthens what is already the leading optimisation offering in the market.

Bi-directional integration with SOT is also one of the major new features of this latest release. This integration utilises an API eliminating the need for file transfers



between the products. Users can pass reserves and dependencies directly from XPAC to SOT so they can explore different strategies to maximise the NPV or several other parameters of the schedule. Once a schedule is optimised the results are integrated back into XPAC Solutions to be visualised, analysed and published.

Another new feature allows users of the open cut coal solutions to import final landform surfaces allowing control of dragline and shovel dumps. Schedules will reflect landform restrictions once the permitted dump height in a particular area has been reached. The resultant schedules are now optimised from a trucking hours and final landform perspective.

Other additions in specific solutions are the support for alternative mining methods within the underground metals solution, simultaneous

mining and backfill of pits within the open pit metals solution, conveyor and strip design import improvements for coal operations as well as improvements to vertical progression for oil sands.

Commenting on the release, Mathews said "This release was focused on delivering enhanced functionality across all commodities, developed with our users, for our global user base".

"This is a release the team can be very proud of", said Mathews, "What you are seeing is the culmination of some very hard work by a lot of people and we are really looking forward to seeing it in the hands of our users".

XPAC Solutions 3.2 is available for all supported software users by contacting the RPM support team or your Customer Success representative.

## Anglo American starts up new coal mine in Queensland

Mining company Anglo American said that its new Aquila mine in Australia had achieved its first longwall shear of steelmaking metallurgical coal on schedule and on budget, marking the project's final stages of construction and commissioning.

Anglo American stated that the Aquila mine, located near Middelmont in central Queensland, extended the life of its existing Capcoal underground operations by seven years after the company's nearby Grasree

mine recently reached the end of its life.

The FTSE 100-listed firm highlighted that Aquila had been developed as "one of Australia's most technologically advanced underground mines", leveraging the company's advancements in underground automation technology, remote operations and data analytics.

Tyler Mitchelson, chief executive of Anglo American's metallurgical Coal business, said: "Safely

starting up longwall mining at Aquila Mine on our original schedule, despite the effects of the pandemic, is an important milestone for our

metallurgical coal business and will support our ongoing contribution to both the Middelmont community, and Queensland's economy."



## Micromine Nexus forms another piece of the puzzle

Micromine has further expanded its suite of digital mining products with Micromine Nexus, a web-based platform that offers a central, secure and streamlined data storage solution for mining projects.

The company developed Nexus in response to customer feedback and built it to be scalable, customisable, user-friendly, and able to satisfy data security and regulation requirements.

Micromine chief strategy and product officer Kiril Alampieski said Nexus epitomised the company as it enables those in the resources sector to get the most from their mining.

"By bringing users, data and technology together, we can help mining organisations build end-to-end digital processes and enable completely new transformative business models," Alampieski said.

"We want to enable clients to use their data to accelerate smart decision making, maximise business opportunities and meet the challenges of delivering a sustainable future."

The last 12 months have seen Micromine expand to become an end-to-end solution from greenfield exploration to mine scheduling and management.

"The solution helps clients overcome the challenges of manual management that often lead to unstructured, redundant and discrepant master data," the company stated on the usefulness of Nexus.

"Users can also stay on top of key activities with

integrated task management tools and automated notifications, ensuring clear, structured and repeatable workflows."

Alampieski said Nexus was just another piece of the puzzle as Micromine solidifies its capability across the mining timeline.

"The launch of Micromine Nexus delivers substantial and immediate benefits to the way clients manage project data and collaboration, while also progressing our longer-term vision for building a fully-connected ecosystem," he said.

In 2021, Micromine acquired Precision Mining and its mine scheduling software, Spry.

Less than three months later, Micromine added another scheduling software, Alastri, to its ranks which chief executive officer Andrew Birch said was a massive achievement for the company.

"Rather than starting from scratch, and building products in competition, we are looking for best in class companies that have proven products and want to grow," Birch said.

"MICROMINE's international footprint, with more than 2,000 sites in 90 countries, represents 35 years of growth and investment that is very difficult for new companies to emulate.

"This way, we bring new products to our clients faster, and give great Australian technology the opportunity to flourish, with the backing of our global distribution, implementation and support teams."



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## From pit to port: value chain optimisation is transforming mining

It is almost always bigger, bolder thinking that can improve how you work, as also protect the world you are working in. This is especially true in the mining industry, where organisations routinely struggle with uncertainty, productivity slumps, energy waste, high maintenance costs, suboptimal asset utilisation and slow decision making.

The reasons for these constraints often boil down to one factor – poor visibility across the value chain.

No wonder mining operations are increasingly turning to digital transformation to connect and visualise the entire value chain.

The advantages include increased throughput, reduced downtime, elimination of redundant operations, efficient energy consumption and ample room for innovations throughout the entire value chain – from the pit to the port.

### Optimising for the new normal

Ramping up visibility also helps a mining organization better adjust to the new normal, where many of its employees and decision-makers are working remotely, or from home.

Deloitte observes that while mining companies have been considering digital transformation for a while, the Covid-19 pandemic has truly accelerated its implementation.

From responding, recovering, and ultimately thriving in the new normal, mining leaders have been presented with a great opportunity to avoid defaulting back to the traditional approach to work.

Instead, they can re-architect work, adapt the mining workplace culture

and create a platform for innovation and collaboration using digital tools.

Moreover, by bringing together data from on-field physical assets and enabling off-field remote and virtual access, “mining companies can improve their abilities to analyse real-time information; augment their digital capacities; and create platforms to integrate their data, analytics, and workflows.”

### Towards a unified supply chain

Mining companies typically struggle from lost opportunities and gaps in understanding when using a menagerie of point solutions.

To remain competitive, they need to regain operational visibility and maximise profits with a transformative approach to production and value chain optimisation.

Deploying unified enterprise applications across the entire supply and demand chains ensures that every facet of the operation is now empowered with analytics and insights.

This invariably transforms the organization



from being reactive to being predictive and allows it to drive operational excellence across the entire mining value chain.

A robust unified decision-making tool is the one that can deliver the means to cut losses along the value chain, enhance collaboration across silos, and decrease the total cost of ownership of various assets.

The solution should be able to seamlessly bridge people, processes, and technologies, while offering enhanced visibility across the whole value chain, from pit to port operations.

It should eliminate the need to have specialists or application experts operating it.

### Meets diverse needs

Perhaps the most important requirement from a unified supply

chain tool is that it needs to be able to collect, store and enhance real-time operational data and enable cloud-based solutions so that anyone in a mining organisation – no matter where they are located or whether they are working remotely from home – can access it.

This also means collaboration across teams becomes easy. Other qualities in a well-rounded tool include the ability to integrate the mining organisations plans with an enterprise resource planning (ERP) and geological modelling system.

This ensures the organisation can be proactive, agile, and responsive during the planning and scheduling stage itself.

It also fuses contractual constraints with operational

constraints. Besides, by modelling the entire supply chain in a single space, the organisation can see all hardware and software constraints in the context of its supply chain, and thereby optimize various KPIs.

Finally, the unified supply chain solution should be able to cater to the mining company's evolving needs – which can change rapidly, especially in this post-pandemic world. It should come with multiple hosting options and be able to scale up or down to always be in sync with current business priorities.

### Connections from pit to port

Australia's leading iron ore mining project, Roy Hill, wanted to build a greenfield mine process plant based on modern control room automation principles. It also wanted to establish end-to-end visibility of the entire

mining value chain.

Their key challenges included eliminating organisational silos, realising resource-to-market potential by avoiding hidden inefficiencies, and being able to connect, automate, and control each component of the pit-to-port mining site from a control centre located 1300 kilometres away from operations.

AVEVA worked closely with Roy Hill to establish a remote operations centre that centralized all roles and functions linking mining operations.

It created a fully integrated, greenfield mine-to-port operation that is controlled remotely while streamlining processes by facilitating collaboration among different functions and creating a high-performance team



connected by a digitised process.

### May the force be with your mine

The World Economic Forum points out that within the mining and metals industry, digitalisation will be the force that changes the nature of companies and their interaction with employees, communities, government and the environment at every step

of the value chain.

“From mineral exploration and valuation, through mining, ore processing and metals production, to downstream sales and distribution, digitalisation is blurring traditional industry lines and challenging the business models of the past.”

In short, optimising the entire value chain will not only open the path to more profits but also to a better future.

## MEC integrates mining services

Global mining consultancy MEC Mining has acquired Integrated Geological Mining Services (IGMS), based in Fremantle, Western Australia, further bolstering its growing capabilities.

IGMS provides dedicated services to the resources industry and covers all aspects of exploration and mining activities.

The company will support Brisbane-based MEC in successfully expanding into WA, by providing a multitude of bespoke services.

MEC chief executive officer Christofer Catania said IGMS will be a formidable addition to the company's growing portfolio.

“IGMS has already built a solid reputation across

the resources sector, successfully consulting with clients on multi-commodity projects across Australia, Europe and South-East Asia,” Catania said.

“Their holistic approach to both exploration and mining dovetails neatly with the MEC ethos, and aligns with our customer-focused approach which values quality end-to-end services to maximise our clients' returns.”

Catania was appointed as MEC Mining's chief executive officer in November last year following a substantial 15 years with the company and said he is confident the acquisition will deliver immediate benefits to the market.

“Since the outset, IGMS has focused on the highest

quality services, outcomes and professionalism, and adopted a collaborative team approach to all aspects of our work. These same values drive the team at MEC Mining,” IGMS director and senior geologist Mike Atkinson said.

Having already diversified and grown the company's offerings with its geotechnical and advisory arm, MEC's latest move

signals significant benefits for mining clients.

With an already proven track record of highly successful project collaborations, Catania asserts the additional experience and complementary knowledge provided by IGMS will support MEC Mining in its mission to deliver unparalleled services to its customers in the resources sector.





## Georgia Power plan confirms move from coal to renewables

Georgia Power Co. could shut down all but one of its coal-fired power plants by 2029 under a new plan filed recently with the state Public Service Commission.

The unit of Atlanta-based Southern Co. filed its integrated resource plan, a document required every three years that tells regulators how Georgia Power plans to meet electricity demand from its 2.7 million customers over the next 20 years.

"You'll have less coal generation; you'll have more renewable generation," Georgia Power CEO Chris Womack said of the plan in a telephone interview with The Associated Press. "You'll have a reliable and enhanced grid that is more resilient."

Southern Co. has set a goal of 2050 to be a net-zero emitter of gases that cause global warming, mostly carbon dioxide. Environmentalists want the company to move move quickly.

Womack declined to say how much the plan might cost or how it would affect rates if approved

by the Public Service Commission. He said those details would be saved for Georgia Power's separate rate plan, scheduled for consideration later this year. However, it's clear that some of the plans, such as transmission improvements to accommodate more renewable power, could be expensive.

The document says Georgia Power could close down all of its coal plants by the end of 2028 except for two mammoth units at Plant Bowen in Cartersville. Most of those moves had already been announced in filings Southern Co. made last year. Georgia Power says it needs to keep burning coal until 2035 at the two Plant Bowen units to guarantee a reliable supply of electricity in metro Atlanta.

The company said it isn't sure whether it will close two units at Plant Scherer near Juliette. Georgia Power says those units, largely owned by others, are economically "challenged" and it would prepare to close them by 2028 while looking for options to keep them

open. The company says that in the meantime, it will seek to build or buy more renewable energy in northern Georgia and plan for the region's power transmission, generation and other needs to guarantee a smooth transmission.

Georgia Power plans to contract with Southern Power, another subsidiary of its parent company, for 2,400 megawatts of natural gas-generated electricity from 2022 to 2028, helping it to bridge coal plant shutdowns with a form of power that still emits carbon, but less than burning coal. The company says it would add 2,300 megawatts of renewable power by 2025 and a total 6,000 megawatts by 2035.

The company said it would build a battery storage facility in Cherokee County, allowing it to capture electricity and release it to the grid several hours later, important for matching the peaks of renewable generation to the peaks of demand. Womack also said Georgia Power wants to explore ways to

store energy for several days.

The company, which operates no wind generation in Georgia, will seek a pilot program to test supertall wind turbines in the state, Womack said.

The plan says nothing new about Georgia Power's plans to clean up coal ash ponds at various locations state-wide. The company had been planning to cap some of them in place, but the U.S. Environmental Protection Agency has recently said that is a misinterpretation of federal rules, despite approval by Georgia's Environmental Protection Division, and that utilities must dig up all coal ash and store it in lined landfills where toxic heavy metals can't seep into groundwater.

The company said it would seek to renew its license to operate the Hatch nuclear plant near Baxley. Georgia Power also said it would seek permission to overhaul three hydroelectric generating plants at Lake Sinclair, Lake Burton and the North Highlands Dam on the Chattahoochee River in Columbus.



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## Nutrien eyes potash production boost

Nutrien, the world's biggest potash miner, could boost production by up to 29% in coming years, depending on any sanctions facing rival producers in Russia and Belarus, the Canadian company's interim CEO told Reuters.

Prices of granular potash fertiliser are near ten-year highs in the United States and Brazil, helped by Western economic sanctions against Belarus. Russia, home of Uralkali and EuroChem potash mines, faces possible economic sanctions if it invades Ukraine.

Uralkali and Belarus Potash Company (BPC) together account for more than one-third of global potash sales, according to BMO Capital Markets.

Soaring fertiliser prices have cut in to farmers' incomes and contributed to global food inflation. Additional potash production may slow rising costs.

Saskatoon, Saskatchewan-based Nutrien could restart up to four-million tonnes of idled annual capacity in that Canadian province in coming years as it assesses the long-term

outlook for sanctions against competitors, interim CEO Ken Seitz said in his first interview since his promotion in January.

"If these are short-lived events, we don't want to spend all kinds of money staffing and opening up ground," he said. "If this is going to be a longer-term problem for the market, we will absolutely do that."

"We will absolutely step into that void."

A Russian troop buildup near Ukraine has stoked fears of war. The United States and United Kingdom are prepared to punish Russian elites close to President Vladimir Putin with asset freezes and travel bans if Russia sends troops into Ukraine, the White House and British government said recently.

As a first step in raising production, Nutrien may raise output by 700 000 to one-million tonnes in the second half of 2022 at low expense, Seitz said, reiterating comments he made last year. Nutrien currently produces nearly 14-million tonnes, representing 19% of global sales.

Seitz could not say how soon Nutrien might restart



the remainder of Nutrien's idled capacity, which would involve more work.

Nutrien has had no talks, Seitz said, in his short time at the helm about any form of potash partnership with BHP Group, which is building a Canadian mine.

Canpotex, the export company owned by Nutrien and Mosaic Co, is fully committed for sales through March 31, illustrating strong demand for Canadian potash.

Global operational capacity, however, exceeds demand by over 10-million tonnes this year, according to BMO Capital Markets.

"In a normal situation, the potash market is oversupplied," said BMO analyst Joel Jackson. "If I was Nutrien, I would probably hold back on my decision to expand too

much too fast."

Additional production from competitors will not fully replace BPC, which previously sold about 12.5-million tonnes a year, said Elena Sakhnova, an analyst at VTB Capital.

The board of Lithuanian Railways voted to stop transporting Belarus' potash, isolating it from a key port.

Russian producers are unlikely to rush to increase their output because of speculation that Washington may grant a waiver to BPC's US buyers, essentially postponing sanctions from taking effect on April 1, Sakhnova said.

A EuroChem spokesperson said the company has no plans to accelerate ramp-up of its new production. Uralkali declined to comment.

Unlike the last time potash prices were this high over a decade ago, there are few advanced junior projects to add production. Construction of a small, 250 000-t Gensource Potash facility could start in Canada this summer, with first output in 2024.

For larger producers, adding additional tonnes is not as inexpensive or simple as they say, Gensource CEO Mike Ferguson said.

"They are so used to just controlling things in the industry and have started to believe their own marketing about having excess capacity," Ferguson said.



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## Dressta adds more muscle to its global management team

Mr. Bartosz Kozik joins the LiuGong Dressta Machinery team as Global Dressta Sales Director

Dressta, the world renowned, full-line dozer manufacturer has strengthened its sales capability with a new, heavy-weight appointment. Mr. Bartosz Kozik joins the LiuGong Dressta Machinery team as Global Dressta Sales Director with full commercial responsibility for developing and implementing Dressta's global sales strategy and managing and expanding its sales and distribution channels. Bartosz brings

with him over 18 years of commercial and strategic experience, having enjoyed senior roles at Volvo CE, Ammann, Ingersoll-Rand, and most recently, as European Business Director for Holms Attachments.

According to Howard Dale, President of the Board at LiuGong Dressta Machinery, "We are delighted to welcome Bartosz to the Dressta team. He joins us at an exciting time of investment, expansion and growth. We are launching a full line-up of next generation dozers including our new TD-15M and our all new,

Red Dot award winning TD-16N. It's our strongest product portfolio to date and we are confident Bartosz's proven ability and enthusiasm will help to take Dressta to the next level."

Commenting on his new position, Bartosz said, "I'm honored to be joining the Dressta team. The Dressta brand is one of the most respected brands in the construction equipment industry with a great history, amazing



people and a bright future. I am excited to have the opportunity to help shape the next chapter in its story."

## Aqura acquired by Telstra after big year with miners

Aqura Technologies has been sold to Telstra for \$30 million, handing a raft of mining infrastructure to one of Australia's leading telecommunications companies.

Aqura parent company Veris has had full ownership of the technology company for six years, but Veris chairman Karl Paganin believed the sale would allow Telstra to facilitate Aqura's growth potential.

"Whilst Aqura has been growing strongly under Veris' ownership, the board is of the view that the timing was right to sell the business to provide the Aqura team the opportunity to accelerate this growth further by accessing Telstra's existing sales and customer channels," Paganin said.

He added that future growth would present opportunities for additional product offerings on top of its current business in industrial wireless-enterprise communications.

Such services have been on show across the mining industry over the past year,

as Aqura signed deals with BHP, Roy Hill and Fortescue Metals Group.

In November, Roy Hill asked Aqura to expand its current private 4G LTE network at its namesake iron ore operation – a network where Aqura was also responsible for its initial construction.

An October announcement saw Aqura agree with DXC Technology to provide an entertainment network across 17,000 rooms at an undisclosed Tier 1 mining village in the Pilbara region.

Multiple contracts were also signed with BHP in August worth a combined \$5.1 million for communications infrastructure upgrades across its Western Australian Iron Ore (WAIO) accommodation precincts.

Not only will Telstra be acquiring a history of relationships with major mining companies, but a future in the development of 5G LTE networks for mining applications.

This was assured by the Federal Government's Digital

Business Plan 5G Innovative Initiative which handed a \$1.9 million grant to Aqura in August.

The federal funding combined with more than \$2 million invested by the company to design a commercially viable installation of a live private 5G network in a functioning Western Australian mine.

Aqura will fall under Telstra subsidiary Telstra Purple – a business arm focussed on digital transformation services – which also acquired Alliance Automation – a leading providers of industrial automation

solutions and control systems.

Telstra Purple senior executive Christopher Smith said Aqura showed plenty of opportunity for growth under the Telstra flag.

"Both companies have demonstrated consistent historical growth, close customer and vendor relationships, backed up by a deep pool of specialist talent with a strong pipeline and growth outlook," Smith said.

"We were impressed by their people, expertise and capabilities and believe they will be very valuable additions to the Telstra Purple team."



# A belt conveyor on rails? Yes indeed!



Mining Technologies

Our game-changing, patented technology elegantly combines the best of belt conveying and rail haulage.

Developed by the University of Newcastle and thyssenkrupp, our rail-running conveyor systems provide additional productivity benefits in overland, steep and pipe conveying. This new technology gives you 20-50% CAPEX savings and 20-60% lower OPEX costs than conventional trough conveyors.

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## Rail-Running conveyor solutions – A Game-changing new belt conveyor technology

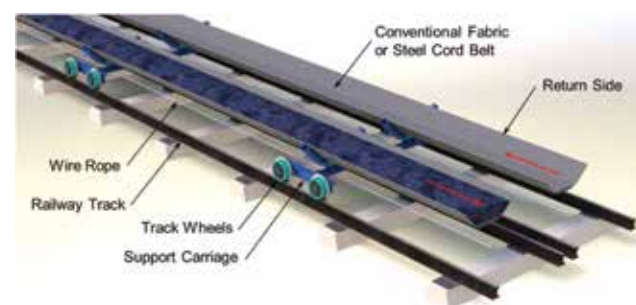
**T**he thyssenkrupp Rail-Running Conveyor™ for overland conveying, and for pipe conveyors longer than 300m.

Transporting bulk materials from one place to another has always been a key element of the mining industry – and a source of challenges. Different terrains, materials and resources have different demands. Thus, innovation marks one of the most important factors in our industry.

Keeping this in mind, thyssenkrupp Mining Technologies and the University of Newcastle are happy to present you a new and sustainable technology to convey bulk materials: The thyssenkrupp Rail-Running Conveyor™.

### INNOVATIVE, SUSTAINABLE, ENERGY-SAVING

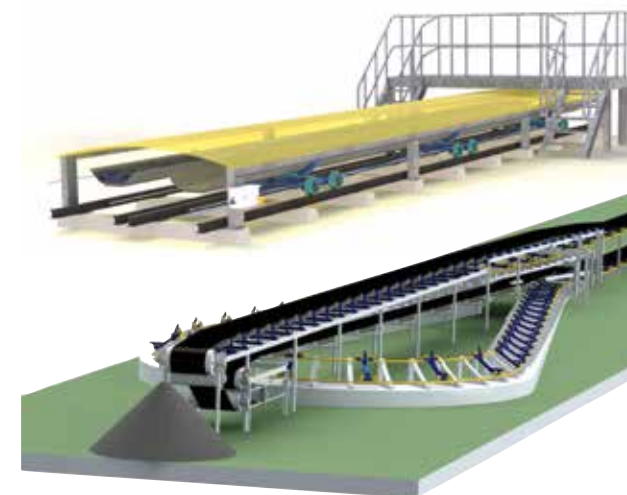
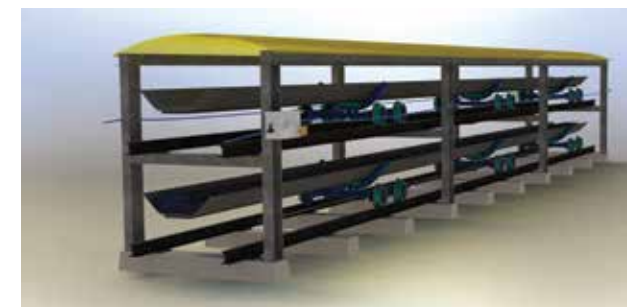
The thyssenkrupp Rail-Running Conveyor™ describes a new and sustainable technology to convey bulk materials. It combines the efficiency of rail transport and the continuity of belt conveying and, through its unique combination of characteristics, overcomes many constraints traditional conveyors suffer from. These mostly relate to the need for regular maintenance and the limitations on speed and movement of the conveyor.



### ELIMINATING CHALLENGES THROUGH CONSTRUCTION

At its core, the construction of the thyssenkrupp Rail-Running Conveyor™ is similar to that of traditional trough and pipe conveyors. Especially the head and tail ends are the same. What sets the Rail-Running Conveyor™ apart is everything happening in between those ends. Instead of a traditional set-up, the belt is carried on light wheeled carts gliding on rails. Here is where the aforementioned improvements of traditional conveyors come in, as the belt is transported on wheel carts, friction and belt tension are lowered severely. This allows for less time spent on maintenance as tear and wear are dramatically reduced, lighter belts, smaller drives and grants the Rail-Running Conveyor™ higher movability. It can now take much tighter curves, both vertical and horizontal, which improves energy efficiency as unnecessary detours are completely eliminated.

Due to the ability to take tighter curves and the no longer needed transfer points along the way, the thyssenkrupp Rail-Running Conveyor™ can withstand extremely challenging terrain, even if it is very rocky or temperatures regularly fall below freezing.



Because the carts now automatically pass by the head and tail ends of the conveyor using a light wire rope, there is also no more need for tedious inspections by walking alongside the belt. This means it can also be applied in remote or near uninhabitable areas since the inspection process is the other way around now: The carts come to the workers.

### ADVANTAGES AT A GLANCE

- The high tonnages and relatively low capital/km of belt conveying, integrated with the efficiency of rail transport.
- CAPEX for supply typically reduced by 20% to 50% compared to conventional long trough and pipe conveyors, thanks to lighter belts, smaller drives, terrain conformity, and fewer transfer points.
- OPEX reduced in the range of 20% to 60%, depending on the particular application.
- Energy losses one third of the most efficient overland trough conveyors, and up to one tenth of pipe conveyors (routes with substantial elevation change see less dramatic energy savings).
- Curvability better than conventional pipe conveyors, so multiple conveyor flights can often be merged into a single-flight conveyor, eliminating intermediate transfers.
- Common conveyor maintenance headaches largely eliminated – such as failed idler rolls, carryback, mistracking, belt flap, idler-ignited fires and transfer-point issues.
- Improved safety – exposure to injuries from idler exchange and transfer maintenance greatly reduced.
- Retro-fits of the system to existing conveyors will usually increase capacity, reduce both energy consumption and maintenance cost, without having to change belt or drives.

### RAIL-RUNNING PIPE CONVEYORS

For short distances and where more flexibility is needed,



the Rail-Running Pipe Conveyor offers a solution. It carries materials within a wide belt that is formed into a pipe along its way as to both protect its cargo from the environment and allow for tighter horizontal and vertical curves than a traditional trough conveyor.



The main difference between a traditional pipe conveyor and the Rail-Running version shows itself once more in the energy efficiency and reduced need for maintenance: Parts susceptible to wear and tear are under significantly less tension as the pipe is no longer drawn through successive rings of fixed idlers and, as the conveyor is now elevated, the need for walkways along its length falls flat. This reduces the weight of the overall structure dramatically and causes it to require less energy for the same output.

### ADDED FLEXIBILITY IN COMBINATION WITH TRUCK HAULAGE

Some plants are suitable to utilize Rail-Running Pipe Conveyors together with traditional truck hauling. In this scenario, the trucks offer flexibility in amount, regularity and speed at which materials are transported, while the conveyor can transport materials consistently, at low cost and more environmentally friendly than trucks.

### ADVANTAGES AT A GLANCE

- Can be used in colder climates
- More energy efficient than traditional trough or pipe conveyors
- Ability for tighter curves allows for higher movability
- Can be used in combination with already existing equipment like hauling trucks

This innovation was only made possible due to the collaboration between thyssenkrupp Mining Technologies and the University of Newcastle. Today, the new Rail-Running Conveyor™ is internationally patented and licensed exclusively to thyssenkrupp in 99% of countries.



# Increasing the efficiency of underground short-hole drilling by combined action of axial and moment pulses

The article substantiates the possibility of improving the efficiency of short-hole drilling by combining axial and moment pulses with a rotating drill cutter. The control of regime parameters of drilling, including parameters of axial and moment pulses, in order to establish rational ratios of parameters can be carried out by boring machines of the mechatronic class directly in the process of short-hole drilling. A methodology has been developed for conducting experimental studies in accordance with which experiments have been carried out and dependencies obtained that reflect the effect of the combined effect of axial and moment pulses on the penetration rate. The stress-strain state of the rock in the undercutter zone of the short-hole with the combined effect of axial and momentum pulses on the drilling tool is investigated using the method of finite element analysis.

Improving the efficiency of the tunneling equipment and reducing the cost of mine workings in modern economic conditions plays a significant role. During the construction of mining enterprises, the volume of mining works is from 30-50% of the total amount of work, and at existing enterprises from 10-30%. With such a proportion of mining works, an increase in drilling efficiency can significantly reduce the cost of work and will have a significant economic effect.

Mining works are carried out in two most common ways: combine and drilling and blasting. Combine method is used if the bottom is composed of rocks with a strength of less than 6 units on a scale of prof. M.M. Protodyakonov, if the strength of rocks exceeds 6 units, then mining works are carried out mainly by drilling and blasting. The use of drilling and blasting method of mining works is widely used due to the large distribution of the corresponding mining and technical conditions. In addition, during drilling, short-hole drilling is used for the construction of roof bolting, and in the construction of tunnels and other underground utilities – to strengthen the arches and adjacent layers of rock. Given that in the drilling cycle, the proportion of

time for direct drilling prevails over other components, an increase in the efficiency of short-hole drilling can significantly increase the rate of tunneling.

## REVIEW AND ANALYSIS OF METHODS FOR IMPROVING THE EFFICIENCY OF SHORT-HOLE DRILLING

Short-hole drilling as a technological process has a history of more than 350 years<sup>1</sup>. Until about the second half of the 19th century, short-hole were manually drilled. Since the advent of mechanization tools, there has been a constant effort to improve the efficiency of the drilling process of short-holes by improving machines and rock-cutting tools. The efficiency of short-hole drilling was proposed to be raised in various ways, which can be divided into two categories: ways to increase drilling efficiency by improving the design of rock-cutting tools and methods implemented by improving the designs of rock-drilling machines, including the introduction of automation tools.

Mining tools, as design objects, must satisfy the requirements of reliability (have high wear resistance and the necessary margin of safety), ensure the destruction of

rocks with minimal energy, have low material consumption, high adaptability in manufacturing and operation<sup>2</sup>. The task of creating and upgrading mining tools was solved at the Platov South-Russian State Polytechnic University (NPI) earlier<sup>3,4,5</sup>, which allowed the creation of a serial cutter for short-holes drilling RP-42, as well as being solved today at the modern technical level using modern computer simulation tools<sup>6,7</sup>.

The drilling equipment was first of all modernized by increasing its power supply. The designs of rotary, rotary-percussive drilling and percussive drilling machines have been developed. However, over time, the increase in drive power reached certain technical limitations and, in a further increase in drilling efficiency, was achieved by controlling the mode parameters of drilling (tool rotation frequency, axial force value, and, in the case of rotational percussive drilling, impact frequency), as well as maintaining them at a rational level throughout the time of short-hole drilling.

Short-holes drilling is a complex multi-factorial process, the management of which, as practice has shown, with enough accuracy is difficult to carry out in manual mode. This circumstance has created the prerequisites for the development and implementation of automation tools

for managing operational parameters of drilling. Such scientists as Professor V.T. Zagorodnyuk<sup>8,9</sup>, Professor G.M. Vodyanik<sup>10</sup>, Associate professor V.A. Yatskevich, Associate Professor E.V. Rylev and a number of other scientists<sup>11,12</sup>. Most of the proposed systems for automating the short-holes drilling were based on the use of various force-moment connections between the drill-rod and the whim. Attempts were also made to create a control system using a cutter-face sensor, however, due to the complexity of the implementation of the idea of creating such a sensor, no expected results were obtained.

In modern conditions, the control system of regime parameters of drilling can be implemented on the basis of mechatronic modules, which combine electromechanical components with power electronics and are controlled using a microcontroller or an onboard computer.

The analysis performed allows us to conclude that the greatest effect in increasing the productivity of short-holes drilling can be achieved by further improving the rock-breaking tool and using modern control systems for operating drilling parameters based on mechatronic modules. Such a control system will allow, by periodically adjusting various operating parameters over the drill cutter durability period or during the short-hole drilling time, to achieve a reduction in specific tool wear and an increase in the theoretical penetration rate<sup>13,14</sup>.

## FORMULATION OF THE PROBLEM

To drill the short-hole in a rotational way, an axial force (Poc) and moment force (Mcr) (Figure 1) must be applied to the tool, which create at the cutting edge of the tool a force  $P_y$  and a cutting force  $P_z$  sufficient to form large chips. Improved drilling efficiency can be achieved through additional shock effects. It is obvious that the

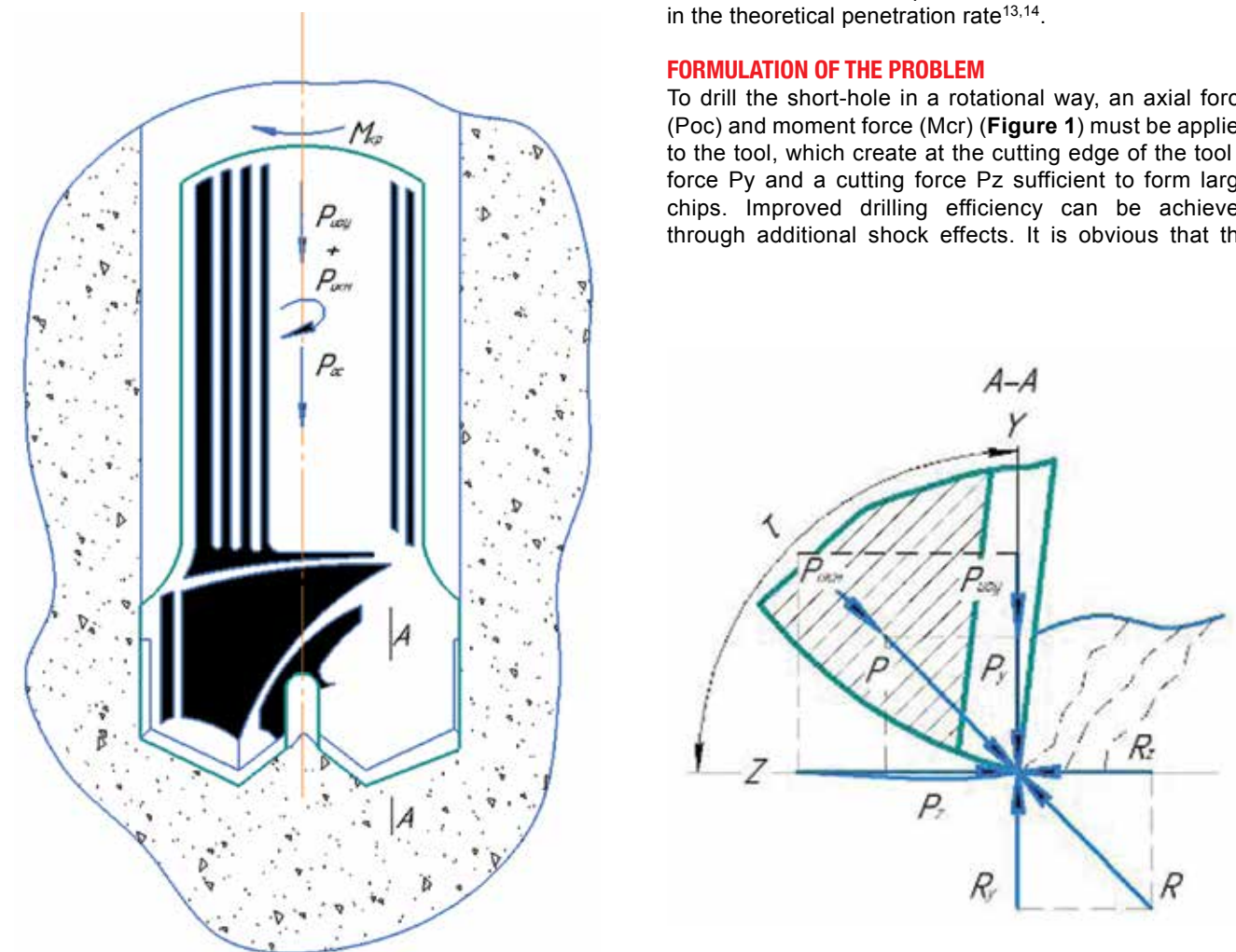


Figure 1: Scheme of operating forces when applying moment and axial pulses:  $P_y$  – axial force;  $P_z$  – cutting force;  $P$  – resultant on the tool;  $P_{ay}$  – axial impulse;  $P_{om}$  – moment impulse;  $R_y$  – resistance of the rock to introduction;  $R_z$  – resistance of the rock to cutting;  $R$  – resultant rock;  $\tau$  – possible area of change in the direction of the resultant  $P$ .



combination of the values of the number of chips and the impact frequency theoretically should coincide in phase, that is, the addition of the vectors of cutting forces, feed and impact load will have a decisive role in increasing the efficiency of rock destruction by the cutting edge of the cutter. However, this process is stochastic and cannot be directly controlled. At the same time, it is obvious that by controlling the direction of the vector P and its value, it is possible to increase the efficiency of rock formations and, as a result, increase the penetration rate. In addition to imposing on the instrument additional pulses of the axial force Piou, it is also possible to superimpose the moment pulses Pico, which allows not only increasing the force P but also ensuring its targeted impact on the rock to be destroyed.

Adding an additional impact on the drilling tool will entail a complication of the algorithm for controlling the regime parameters of drilling and, as a consequence, the cost of the rock-drilling machine, but ultimately will increase the efficiency of rock destruction at the face. To improve the efficiency of drilling, it is proposed to additionally influence the drill cutter with axial and moment pulses in various combinations.

In this regard, there is a need for an experimental study of the combined effect on the drilling tool of axial and moment pulses, as well as the study of the stress-strain state of the rock mass in the undercut zone caused by such an impact on the drilling tool.

## THEORETICAL PART

To carry out experimental studies of the combined effect of the axial and moment pulses on the drilling tool, the original design of the drilling stand was used<sup>15</sup>. Previous studies have shown a nonlinear dependence of the penetration rate on such operating parameters as rotational speed<sup>16,17,18</sup>, frequency and energy of axial pulses, therefore, when developing a methodology for conducting experimental studies, a second order plan was chosen. As a plan for the experiment, a rotatable central compositional plan (RSCP) was chosen, which allows predicting the response function values with the same accuracy in all directions at the same distance from the center of the experiment plan<sup>19</sup>. Experimental studies were conducted on cement-sand samples with a diameter of 70 mm. The contact strength of rock samples was determined by the method L.I. Baron and L.B. Glatman on the hydraulic press PSU-10. A short-hole was drilled using the BI-741 model with a coal cutter with a scale factor of 4 on the modes corresponding to this scale factor<sup>20</sup>. The study of the stress-strain state of the rock mass in the undercut zone was carried out using a finite element analysis.

## RESULTS OF EXPERIMENTAL STUDIES

The study of the effect of the combined effect of axial and moment pulses on the drilling tool was carried out in the range of rotation frequency of 200-360 min<sup>-1</sup> and the frequency of axial and moment pulses in the range of 2200-4000 pulse/min. These ranges of values were selected based on the known recommendations on the speed and rational angle of rotation of the tool between the axial pulses<sup>17</sup>. 3 groups of rocks with contact strength P<sub>k1</sub> = 500 MPa, P<sub>k2</sub> = 600 MPa and P<sub>k3</sub> = 700 MPa were selected for the experiment.

As a result of the experiment and data processing, regression models were obtained, reflecting the effect of the combined effect of axial and moment pulses on the penetration rate of the short-hole:

- rocks with contact strength P<sub>k1</sub> = 500 MPa

$$V_{k1} = -1,02 \cdot 10^{-6} \cdot n_{\beta}^2 + 9,48 \cdot 10^{-4} \cdot n_{\beta} - 8,77 \cdot 10^{-9} \cdot n_o^2 + 5,75 \cdot 10^{-5} \cdot n_m - 1,48 \cdot 10^{-5} \cdot n_o +$$

$$+ 9,85 \cdot 10^{-9} \cdot n_m \cdot n_o - 0,036$$

- rocks with contact strength P<sub>k2</sub> = 600 MPa

$$V_{k2} = -9,59 \cdot 10^{-7} \cdot n_{\beta}^2 + 8,5 \cdot 10^{-4} \cdot n_{\beta} - 8,35 \cdot 10^{-9} \cdot n_o^2 + 4,95 \cdot 10^{-5} \cdot n_o - 1,31 \cdot 10^{-5} \cdot n_m +$$

$$+ 9,19 \cdot 10^{-9} \cdot n_m \cdot n_o - 0,006$$

- rocks with contact strength P<sub>k3</sub> = 700 MPa

$$V_{k3} = -9,24 \cdot 10^{-7} \cdot n_{\beta}^2 + 7,89 \cdot 10^{-4} \cdot n_{\beta} - 7,83 \cdot 10^{-9} \cdot n_o^2 + 4,34 \cdot 10^{-5} \cdot n_o - 1,24 \cdot 10^{-5} \cdot n_m +$$

$$+ 8,87 \cdot 10^{-9} \cdot n_m \cdot n_o - 0,014$$

where n<sub>β</sub> – the tool rotation frequency, min<sup>-1</sup>; n<sub>m</sub> – is the frequency of the moment pulses, pulse/min; n<sub>o</sub> – frequency axial pulse, pulse/min;

Evaluation of the statistical significance of the coefficients and the adequacy of the regression equations was carried out by the criterion of Student and Fisher, respectively. As a result of the verification of the regression equations at a significance level of α = 0.05, it was determined that the resulting regression models with a probability of at least 95% adequately describe the phenomenon under study.

For the regression equation obtained by drilling rocks with a rock strength of P<sub>k3</sub> = 700 MPa with a combined effect of axial and moment impulses, graphical dependencies were constructed (Figure 2).

A comparative characteristic of the rotational method of drilling with a method with a combined effect on the drill cutter in the form of axial and moment pulses is shown in Figure 3.

The study of the stress-strain state of the rock mass in the undercut zone while drilling with the combined action of axial and moment pulses on the drill cutter was carried out using the finite element analysis method. As a result of modeling a section of the cutting edge of the drill cutter, 1 mm wide, in the drilling mode with a combined effect of axial and moment pulses on the rock with a Young's modulus of E = 1 · 10<sup>9</sup> Pa and a Poisson coefficient μ = 0.3, a picture of the stress-strain state of the rock was obtained in the undercut zone shown in Figure 4.

From Figure 4a it can be seen that when drilling in a rotational mode, approximately the same stress and strain fields occur in front face of the tool and under the cutting edge. With an additional impact on the drill

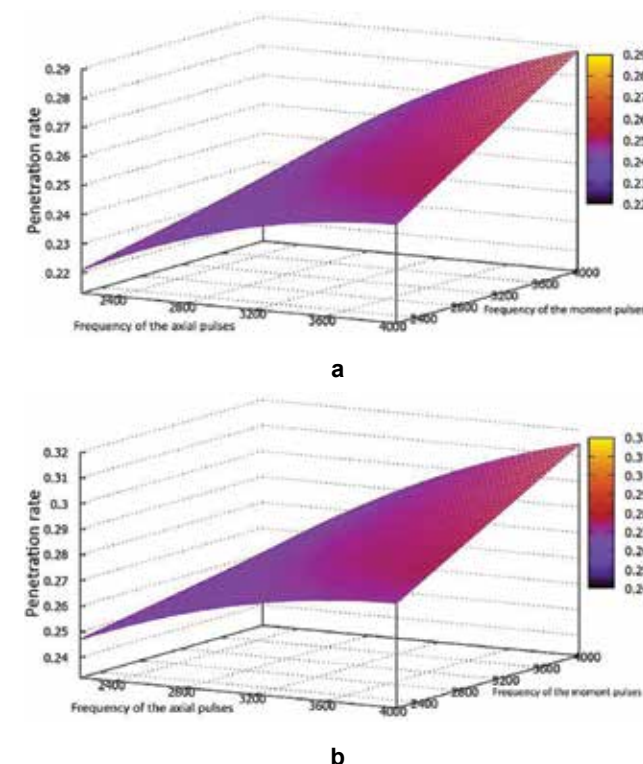


Figure 2: The response surface of the regression model for rock samples with contact strength P<sub>k3</sub> = 700 MPa at tool rotation frequencies: a – 200 rpm; b – 360 rpm.

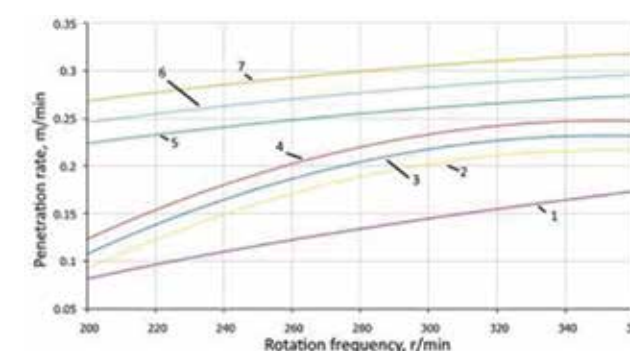


Figure 3: Comparative characteristics of the rotational method of drilling with a method with a combined effect on the drill cutter: 1-rotary drilling; 2,3,4-drilling with a combined effect of axial and moment pulses with a frequency of 2200/2200, 3100/3100, 4000/4000 imp / min, respectively.

cutter axial pulses, the tool is additionally introduced into the rock, which ensures the volume destruction of the rock, albeit with increased specific energy costs. This is indirectly indicated by the picture of the stress-strain state of the rock massif, shown in Figure 4b. In the case when, during rotational drilling, the drill cutter is combined with axial and moment pulses in the rock mass, additional shear stresses occur, which ensures a less energy-intensive fracture process, reduces the friction forces between the rock and the tool<sup>21</sup> and, therefore, provides a higher penetration rate. From Figure 4c it is clear that the stress and strain fields in the rock mass in front edge of the cutter appear to a greater extent than in other cases.

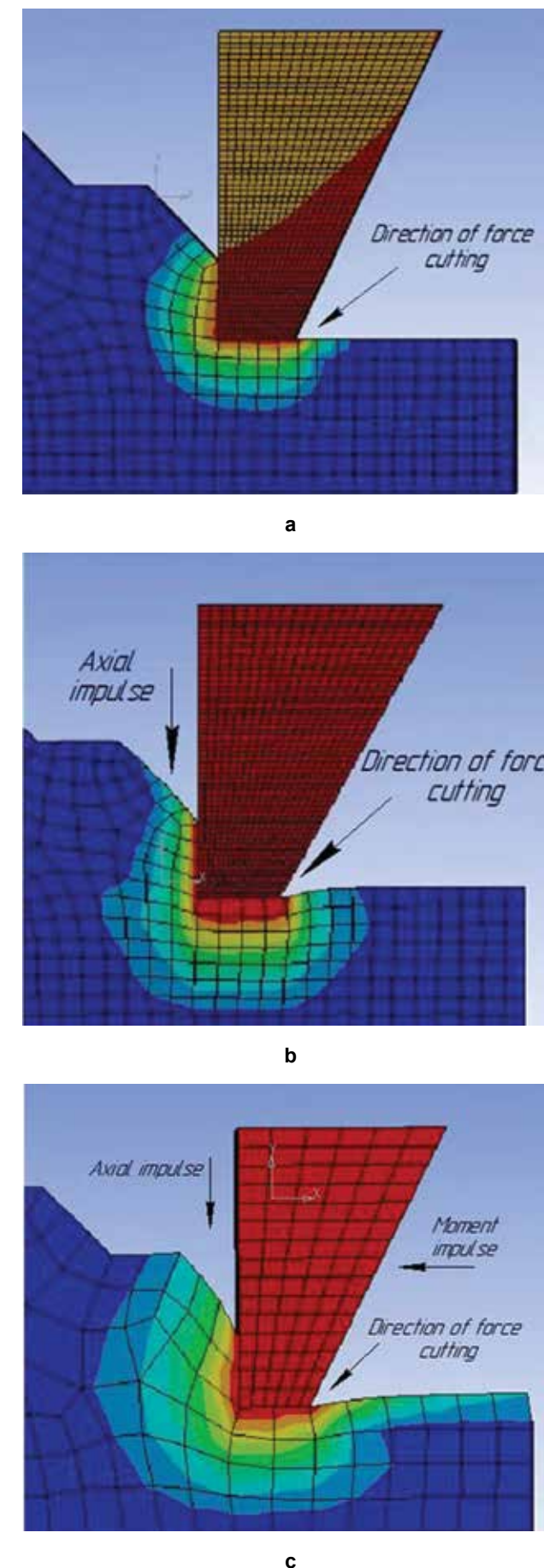


Figure 4: Stress-strain state of the rock mass when drilling in the rotary mode (a), with the additional impact of axial pulses (b), with the combined effect of axial and moment pulses (c) on the drilling tool.



## CONCLUSIONS

As a result of studies of short-holes drilling with a combined effect of axial and moment pulses on the drilling tool, the following conclusions were made.

1. Improving the drilling efficiency can be achieved by further improving the rock-breaking tool and using modern control systems for operating drilling parameters based on mechatronic control modules.
2. Experimental studies of the combined effect of axial and moment pulses on a drill cutter have established that in the rotation frequency ranges of 200-360 min<sup>-1</sup> and pulse frequencies of 2200-4000 pulses/min, the penetration rate increases 1.78 - 3.14 times, depending on selected modes.
3. By the method of the finite element analysis, it has been established that the combined effect of axial and momentum pulses on the drilling cutter allows to increase the efficiency of drilling due to the additional shear stresses in the rock mass in front edge of the drilling tool.

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## Necessity driving innovation for world's Tier 1 miners

In 2022, the world is rapidly moving to combat the looming climate crisis. Sources of low-emission, greener energy are becoming increasingly vital. As a result, hydrogen is emerging as a fuel that can help the world achieve its aims. The hydrogen economy is growing rapidly as necessity drives innovation, and the mining industry is jumping on the bandwagon alongside the challenging application for equipment manufacturers of further developing all electric haul trucks.

Burning hydrogen is clean and almost waste-free, and it's an extremely versatile fuel for powering all kinds of appliances, in conjunction with batteries. Renewable energy sources like wind and solar power have the capability to meet the needs for electrical power, but it also needs scalable solutions for mobility, to replace the petrol, diesel and other fossil fuels that are consumed by most vehicles all around the world every day. It's a massive technological challenge to the mining industry but one that will deliver huge returns for those involved in shaping the future.

Decarbonising haul truck fleets is a critical step forward on the road to carbon neutrality and mining companies are collaborating with the major equipment manufacturers to provide solutions.

### CHALLENGE

Mining giants BHP, Rio Tinto, and Vale have launched a challenge to accelerate the electrification of the surface mining industry to slash emissions, but also make industry safer and more productive. Rio Tinto is the founding patron.

The three largest mine operators in the world, along with Australia's Mining Equipment, Technology and Services (METS) industry body Austmine, have founded the Charge on Innovation Challenge to invite technology innovators worldwide to develop new concepts for electric haul trucks that could be used on a widespread scale.

It has been stated there are an estimated 50,000 off-road haul trucks that weigh over 90 metric tonnes in operation around the world and an additional 68,000 that are inactive. Together, these vehicles account for the largest proportion of registered mining vehicles, and with some weighing as much as 500 tonnes, their electrification will have by far the largest impact on reducing emissions in the industry's fleets.

"Innovation is the key to decarbonisation, and we expect the Challenge will deliver exciting new concepts that could drive huge long-term benefits for our industry and the

environment," said Rio Tinto Group executive for safety, technical and projects Mark Davies.

But with large trucks come large challenges. The Charge on Challenge seeks to solve, at least in part, the issue of how to keep the high-capacity batteries needed to power electric haul trucks charged throughout their daily routine of load, travel, dump, return and queue.

Current stationary charging solutions require substantial time to charge a truck and are unsuitable for charging a truck within the haul cycle for example while it is being loaded or it is dumping. This would require miners to purchase many more trucks. One solution has been to adapt trolley assist systems which are currently used to propel diesel-electric trucks to power battery-electric trucks during their day-to-day operations.

The announcement of the challenge comes just months after fellow Australian mining major Fortescue inked a deal with Williams Advanced Engineering (WAE) based in the UK to develop its own battery-electric haul truck. It was also reported later that

the company intended to buy the battery and technology division of the Williams Formula One racing team for £164 million (\$222 million).

Williams Advanced Engineering (WAE) is owned by EMK Capital and Williams Grand Prix Engineering. The goal of the deal is to help Fortescue Metals to achieve its target of being carbon neutral by 2030. WAE will be integrated into Fortescue's clean energy unit. The mining company is reported to have been developing a battery for heavy industrial use since early in 2021.

Andrew Forrest, Fortescue's founder and chairman is reported to be Australia's richest person, with an estimated net worth of £13.3 billion (\$18 billion). He is aiming to transform the world's fourth-largest iron ore producer into a leading clean energy producer.

WAE also partnered with mining giant Anglo American and energy Engie in 2020 to develop and test a 290-tonne hydrogen fuel cell haul truck, thought at the time to be the world's largest electric dump truck.

### CAT

More recent well documented activity has been Canadian producer Teck ordering 30 Cat all electric trucks for its operations. The companies plan to progress through a multi-phased approach together that includes early development, piloting, and deployment of 30 Caterpillar zero-emission vehicles, including Cat 794 ultra-class trucks beginning in 2027.

Teck anticipates initially deploying zero-emissions trucks at its Elk Valley steelmaking coal operations in British Columbia, Canada. The operations are already powered by a 95% clean electricity grid, making it an ideal location to introduce one of Canada's first zero-emissions large haul truck fleets, with options for trolley-assist technology.

This followed last year's announcement that the world's first operational deployment of approximately 35 new Caterpillar 793 zero-emissions autonomous haul trucks will



be at Gudai-Darri once development is complete. Gudai-Darri is one of Rio Tinto's most technically advanced iron ore mines, in the Pilbara, Western Australia.

### KOMATSU

Last year Rio Tinto also announced that it was also partnering with Komatsu to fast-track the development and implementation of zero-emission mining haulage solutions, including its haul trucks. Rio Tinto will conduct a pre-production trial of the new equipment at a Rio Tinto site and has the option to purchase some of the first trucks from Komatsu once they are commercially viable.

Alf Barrios, Rio Tinto's Chief Commercial Officer said at the time of announcement "Rio Tinto and Komatsu have a shared history of partnership on innovation going back to when we built the world's largest Komatsu autonomous haulage fleet in 2008."

"Our support of a trial, and the option to buy some of the first trucks from Komatsu, underscores our shared commitment to actively collaborate on product planning, development, testing and deployment of the next generation of zero-emission mining equipment and infrastructure as we look to decarbonise our business."

Rio Tinto is also one of the first companies to join Komatsu's newly launched Greenhouse Gas (GHG) Alliance which has an initial target of advancing Komatsu's power agnostic truck concept for a haulage vehicle that







Trevor Barratt-Managing Editor looks at a case in British Columbia at Copper Mountain mine that is utilising a trolley assist system in its efforts to combat zero emissions.

#### BC HYDRO

As a Provincial Crown corporation, the owner and sole shareholder of BC Hydro is the Province of British Columbia. The company is most certainly making inroads to achieve net zero emissions and Copper Mountain mine is taking the electrifying first step.

The Copper Mountain mine is located about 20 km south of Princeton, British Columbia and 300 km east of the port of Vancouver. The Copper Mountain mineral claims cover approximately 18,000 acres and consist primarily of 135 crown grants, 176 mineral claims and 14 mining leases. The property is accessible by a combination of highways and paved roads and is close to the port of Vancouver that provides service for shipment of copper concentrates. The Copper Mountain mine is a conventional open pit, truck and shovel operation. The mine has a 45 ktpd plant that utilizes a conventional crushing, grinding and flotation circuit to produce copper concentrates with gold and silver credits. A second mill expansion to 65ktpd is also planned, which is expected to further increase average annual production to 139 million pounds of copper

When you examine a mine's carbon footprint, diesel's the devil. For decades, it has been the go-to fuel for mining operations, from haul trucks to other equipment including drills. So how does a mining operation such as Copper Mountain mine, take steps toward chasing a net-zero emissions objective by 2035?

The answer is by installing a one-kilometre section of electric trolleys designed to help 11 full-size hybrid Komatsu trucks haul ore uphill from the main mining pit to the operation's primary crusher. One could think of it as the mining equivalent of the overhead trolleys that have powered public buses in Metro Vancouver since 1948.

The trolley-assist operation is the first of its kind in North America, and it's another example of how B.C. is increasingly powered by water. Using clean and renewable hydroelectric power to shift B.C. homes, businesses and industry away from fossil fuels is a major plank in the Province of B.C.'s ambitious climate action plan.

The Copper Mountain mine, located 20 km south of Princeton in B.C.'s southern interior, produces around 100 million pounds of copper equivalent per year. Managing environmental responsibilities is integral to the mine's operations. Copper Mountain is aligned with the Paris Agreement and aims to reduce carbon intensity by up to 50% in five to seven years, en route to an aggressive goal of net-zero GHG emissions by 2035.

And key to that is the installation of the one-km electric trolley assist in the spring of 2022. Each truck is expected

to displace the use of 400 litres of diesel per hour, or about a tonne of CO2 emissions.

"We first started exploring trolley assist back in December 2016," says Walt Halipchuk, Copper Mountain's director of sustainable business development and the person who has overseen the project from its inception. "Then in 2019, BC Hydro funded a feasibility study, and that's when it really shifted gears."

BC Hydro's key accounts and industrial marketing teams collaborated with Copper Mountain to secure funding.

"We also won funding for GHG projects from CleanBC the same year, along with a second grant in 2020," explains Halipchuk. "We began by developing the ramp, moving eight million tons of material to build it. Obviously, we have the equipment right here at the mine to do that, and it moved along at a good pace, but with so many switchbacks along the roads in the mine, it was quite an undertaking."

#### BIG MATH: HOUSE-SIZED TRUCKS CAN MOVE TWICE AS FAST ON ELECTRIC DRIVE

At almost 15 metres long by seven metres high and eight metres wide, the Komatsu 830E-5 hybrid trucks are bigger than the average two-storey house. And, when loaded, they can weigh in at over 900,000 pounds, or 409 metric tonnes. That's the equivalent of 30 loaded transit buses, or nearly 300 cars.

Equipped with a 2,600-horsepower diesel motor, the hybrid trucks are also equipped with an electric drive system that requires three megawatts of peak power to make it move. The trucks can only run on their electric drive motors when they're connected to the trolley assist. But move they do, at a speed of up to 35 km/h, more than double the top speed of what the diesel motor can manage.

The BC Hydro Interconnections team worked throughout 2021 to ensure that Copper Mountain can access the additional load needed to power the project. The finished trolley system can consume 12 megawatts at any one time – enough for four trucks to be on the ramp hauling while the other seven are loading or unloading elsewhere in the pit.

I've got over 30 years' experience building mines in Peru, the Dominican Republic and northern B.C., but this is the most challenging project I've ever done in my career," says Halipchuk. "We needed to integrate the needs of the mine, the brand-new hybrid haul trucks and the critical electrical infrastructure – they all have to work together perfectly."

#### WHY COPPER MOUNTAIN HAS INVESTED \$40 MILLION IN TROLLEY ASSIST

The Copper Mountain trolley assist project has cost around \$40 million, and two more phases of trolley assist are planned. The mining company is counting on that investment paying off for a number of reasons:



Four Komatsu hybrid trucks at a time will be able to climb, via electric trolley assist, up a one-kilometre hill from the pit at Copper Mountain mine near Princeton to the operation's primary crusher. (Visualization courtesy of Copper Mountain Mining Corporation).

- Rising carbon taxes. As carbon taxes rise, the trolley assist will help to dramatically reduce Copper Mountain's liability.
- Rising diesel prices. Each hybrid Komatsu haul truck will displace 400 litres of diesel (or 1 tonne of CO2) per hour while working via trolley assist. Plus, moving to BC Hydro's clean electricity creates a more stable costing model compared to relying on volatile diesel prices and supply.
- Faster trucks. While using trolley assist, the hybrid trucks enable Copper Mountain to haul more ore in less time.
- More responsible metals. The BC Government is helping B.C.'s mining industry establish "responsible metals" credentials to products as they transfer along the supply chain, so that these products can then be traded at a premium. The "responsible metals" label will make Copper Mountain's product more valuable.

#### MINE WANTS TO SPREAD THE WORD ABOUT TROLLEY ASSIST BENEFITS

As one of the few mines in the world with working electric trolley assist – the first was Boliden's Kevitsa mine in Finland – Copper Mountain is keen to spread the word.

"This has gathered a lot of interest from other mining companies, especially in Canada," says Halipchuk. "So we're having a symposium to meet with other mining companies, and sharing our learnings."

Copper Mountain also plans to host a public demonstration of the trolley assist project on May 25, 2022, during BC Mining Week.

"People can come and see the trolley assist up close and join us for a big community day in Princeton town square," says Halipchuk.

can run on a variety of power sources including battery and hydrogen.

Max Moriyama, President, Mining Business Division of Komatsu Ltd said Komatsu was honoured to continue to partner with Rio Tinto.

Codelco like the rest of the world's Tier 1 miners is betting on zero emission mining trucks and was a founder member of Komatsu's GHG Alliance. The largest copper producer in the world and the main Chilean state-owned company says it is accelerating its path towards carbon neutrality by 2050, seeking to eliminate diesel from its open pit mining trucks.

BHP also jumped on board Citing in its Climate Change Report 2020, BHP stated its role within the partnership will be to provide engineering and technical resources to Komatsu to support the real-time development stage of the vehicles. Komatsu will utilize the leading Tier1 companies' expertise in the mining industry to increase its time to market for the zero-emission haul trucks.

James Agar, BHP Group Procurement Officer stated at the time, "We are excited by the opportunity to work with the Komatsu GHG Alliance to drive new technology and innovation that can benefit the mining industry globally. This collaboration is a great example of the partnership approach we are taking in our supply chain as we work towards BHP's goal of net-zero operational emissions by 2050."

Max Moriyama, President Mining Business Division with Komatsu Ltd. noted, "We are thrilled to welcome BHP to this exciting new customer alliance and ready to see how we can all work together towards a more sustainable future and rapid development of zero-emission equipment solutions."

It will be interesting to see how BHP retrofits its service trucks once it launches its zero-greenhouse gas emission hauling trucks.





## REACH for safety

### Are your conveyor belts safe to handle?

**W**hen **REACH** (Registration, Evaluation and Authorisation of Chemical substances) regulation EC 1907/2006, first came into force in June 2007, it is fair to say that it largely went unnoticed by the conveyor belt industry. However, thanks largely to the benefit of 14-years of hindsight, most of us are now far more aware of the



We have a duty of care to our families, our colleagues and the environment.

importance and reasoning behind such regulations and the enormous duty of care we owe not only to our families and ourselves but equally to work colleagues and customers.

Since its inception, the various component parts of REACH regulations have continued to develop in line with ongoing scientific research. Not only have the goalposts moved, the playing field itself seems to be moving. Here, one of the industry's leading conveyor belt application engineer's, Rob van Oijen, brings us up to date with the regulations and issues a stark warning to those who continue to turn a blind eye to the very genuine safety aspects involved.

#### WHY WORRY?

The reason why the levels of hazardous chemicals used to make conveyor belts is such a cause for concern is twofold. Firstly, there are the proven harmful effects that 'substances of very high concern' (SVHC's) can have on humans and the environment. Secondly, and equally important, there is an ever-growing list of substances still under research that are suspected by scientists to have potential harmful effects. Sadly, history is littered with examples of substances (asbestos for example) that were thought to be harmless at the time but ultimately proved to have seriously damaging long-term effects.



Those physically working with conveyor belts need to be safeguarded.

suspicious chemicals and build and maintain a public database in which consumers and professionals can find hazard information.

The Regulation also calls for the progressive substitution of the most dangerous chemicals (referred to as "substances of very high concern") when suitable alternatives have been identified. One of the primary reasons for needing stricter regulation was that as modern technology advanced at pace, new substances were regularly being developed and introduced into the market in Europe without sufficient research data or regulatory safety control. Most of these new substances lacked information on the potential hazards that they might pose to human health and the environment. One of the key objectives of REACH was therefore to fill these information gaps to ensure that industry is able to assess hazards and risks of the substances, and to identify and implement the risk management measures to protect humans and the environment.

As far as conveyor belts are concerned, those who regularly work with them as part of their job role, such as conveyor maintenance staff and belt splicers for example, are potentially at greatest risk and therefore most in need of safeguards. Fortunately, at least as far as Europe is concerned, very strong regulations are in place to protect humans and the environment in the form of REACH.

#### WHAT IS REACH?



REACH was established by members of the EU with the specific aim to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. This is achieved by the four processes of REACH, namely the registration, evaluation, authorisation and restriction of chemicals.

"No data no market": The REACH Regulation places direct responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. Manufacturers and importers are required to gather information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database in the European Chemicals Agency (ECHA) based in Helsinki. The Agency is the central point in the REACH system. It manages the databases necessary to operate the system, co-ordinates the in-depth evaluation of

#### THE USE OF CHEMICALS IN CONVEYOR BELT MANUFACTURING

The vast majority of the rubber used to make modern-day conveyor belts is actually synthetic or, at most, contains only a relatively small element of natural rubber. In basic scientific terms, the creation of rubber compounds (rubber compounding) is the process where a range of 'specific task' chemicals, reinforcements, resins and a variety of other substances are mixed together with rubber polymers.

The most common polymers used in conveyor belts are Styrene- Butadiene rubber (SBR) and Nitrile rubber (NBR). The chemical agents form chains of polymers to form rubber compounds that will ultimately be vulcanised to create the finished product.

There are literally dozens of different components that are used to create the various rubber compounds, such as anti-degradants, anti-ozonants and also as accelerators (essential for the vulcanisation process for example). These components include primary amine-based sulfenamides, such as N-cyclohexyl-



SVHC – Substances of very high concern.





Hundreds of different chemical components are used to create rubber compounds.

2-benzothiazole sulfenamide, and thiazoles, such as 2-mercaptobenzothiazole. It is an inescapable fact that to make some rubber compounds it is necessary to use chemicals that are extremely dangerous in their own right. What REACH does is strictly limit the amounts of certain chemicals that are used in each product, encourage safer substitutions and, in some extreme cases, ban them altogether.

## SOMETHING SMELLS WRONG

One of the biggest concerns involves short-chain chlorinated paraffins (SCCP's). These are commonly used to accelerate the vulcanizing process. REACH regulations clearly stipulate that SCCP's should either not be used at all or at least only used on a very restricted basis because of their category 2 carcinogenic classifications. Their presence can usually be identified by the unpleasant smell of the rubber whereas good quality rubber usually has very little smell at all.

The formation of nitrosamines gasses is another cause of concern and known to occur when certain types of vulcanisation accelerators are used. Nitrosamine gasses can release themselves from rubber belts, which could particularly be a problem when the belts are stored indoors. Nitrosamines are chemical compounds classified as probable human carcinogens on the basis of animal studies. Investigative research is still ongoing but publicly available information from the rubber industry (primarily from within

Germany and The Netherlands) indicates that nitrosamine formation can be avoided if the accelerators are replaced by others that do not contain nitrosatable substances.

## ACCOUNTABILITY AND RESPONSIBILITY

Perhaps not surprisingly, nearly all European conveyor belt manufacturers have chosen to ignore REACH requirements, either completely or at least partially because of the impact on production costs. Raw materials, all of which are readily available on the open market, make up more than 70% of the cost of producing an industrial conveyor belt. Competition is fierce and largely driven by the selling price. As with all markets, unregulated (in this case non-REACH compliant) raw materials cost appreciably less than regulated materials. This creates an extremely significant selling price advantage for those willing to ignore the regulations.

Manufacturers located outside of EU member states and the UK are not, of course, subject to the regulations. Neither are they subject to EU regulation concerning Persistent Organic Pollutants (POPs). This provides them with an open door because they are free to use unregulated raw materials even though those same materials may be entirely prohibited or at least have strict usage limitations within the European community.

Although importing belts that use materials that are forbidden to be used in Europe is still legally permissible, it is worth noting that the European-based trading companies who import belts from outside of Europe are responsible for the application of REACH regulation. This effectively means that the actual manufacturers are free of responsibility and the consequences while the importers of their products are likely to be totally unaware of the risks that they are exposed to. It is not only traders who are exposing themselves to risk. At Dunlop we manufacture all of our belts (including the rubber) ourselves using our own facilities so we know for sure that we are fully REACH compliant. However, the vast majority of European manufacturers import at least part of their product range from outside of Europe to supplement their production and allow them to compete at the 'bargain basement' end of the market.

## REACH AND THE UK FOLLOWING BREXIT

REACH, and other chemicals regulations, were retained in UK domestic legislation at the end of the Brexit transition period via the European Union (Withdrawal) Act 2018. Secondary legislation was also passed that amended REACH to make it work in a UK-only context from that point onwards. The UK Government put in place a separate UK REACH regime that applies to businesses



Manufacturers outside of EU member states and the UK are not subject to REACH or EU regulation concerning Persistent Organic Pollutants (POPs).



Good quality rubber usually has very little smell at all.

that import, make, sell or distribute chemicals in Great Britain, whether as raw materials or in their finished state.

The UK REACH Regime was designed to establish a UK-wide market for chemicals applying to all chemical substances manufactured and imported into the UK, with the Health and Safety Executive (HSE) established as the UK REACH Competent Agency, taking over the functions of the ECHA. Under the Northern Ireland Protocol, however, the EU REACH Regulation will continue to apply to Northern Ireland after the end of the transition period, while UK REACH will regulate the access of substances to the market in Great Britain, as set out in the EU Exit Regulations of 2020. The UK REACH regime is designed to replicate the EU system as closely as possible, maintaining the fundamental aims and purposes of REACH including high standards of health and environmental protection.

## PROGRESSIVELY TOUGHER

Anything to do with science is a process of continual evolution. Particularly since 2018, REACH regulation regarding SVHC (substances of very high concern) has become increasingly stringent and demanding. Previous REACH compliance was largely based on declaring (registering) the use of listed chemical substances and staying within specific limits applicable to each substance. Now, Article 31 of REACH (requirements for safety datasheets) demands that if a product contains SVHC that is more than 0.1% of the total weight of the finished product then the manufacturer is compelled to both register its use with the European Chemicals Agency and provide their customer with a safety datasheet.

Accurately calculating the total proportion of weight relating to SVHC for an individual product is quite a painstaking task. However, there is no doubt in my mind that it is entirely necessary. At Dunlop, we review and calculate the weight of SVHC in all of the materials that we use in each individual product. This includes materials that we buy from outside sources such as resin for example. The combined weight of SVHC is calculated as a proportion of the gross weight of the product. Not only do the proportions differ depending on the composition of each product type, they also differ depending on the thickness of the rubber covers. The proportion in terms of



The combined weight of SVHC should not exceed 0.1% of the actual product weight.



Wear a mask to avoid inhaling rubber dust.

weight is naturally higher in thinner, lighter products. As a responsible company, that is a fact that we simply have to accept. As I mentioned earlier, at Dunlop we manufacture our own rubber and we make every belt ourselves so we have total control. What worries me is that the majority of belt used in Europe nowadays is imported from outside of Europe, mostly from Asia, so it is virtually impossible to know how much SVHC and Persistent Organic Pollutants (POPs) these belts contain.

## WORKING SAFE

Brussels is often accused of over-zealous regulation but the use of potentially harmful chemicals and materials should not be compared with regulations concerning the straightness of bananas or the size of eggs. Although it certainly is not my intention to scaremonger, it is nevertheless important that users of rubber conveyor belts make themselves aware of potential hazards. Always ask for written confirmation from the belt manufacturer or supplier that the product you are buying has been produced in compliance with REACH EC 1907/2006 regulations.

At the same time, basic safety precautions for those working with conveyor belts should be applied. Firstly, wear gloves (if practical) when handling belts. Secondly, it is advisable to wash your hands before drinking, eating or smoking. Lastly, those involved in actions that may cause rubber dust to be produced, such as grinding for example, should wear a mask to prevent inhalation of dust particles.



## ABOUT THE AUTHOR

**Rob van Oijen** is Manager Application Engineering for Dunlop Conveyor Belting in The Netherlands. Rob has specialised in conveyors for some 14 years, supporting businesses throughout Europe, Africa, the Middle East and South America.



# Raise Boring a flexible mining method

*Mining & Quarry World* studies the concepts of shafts constructed by raise boring in underground mines.

The conventional raise boring methods, such as the wood support method, the hanging cage method, the creeping cage method, and the deep-hole blasting method are all areas that have played a significant part in this crucial mining operation, however, in addition to this Raise Boring machinery and its associated technologies have progressed over the years, allowing greater depths, diameters and flexibility to be achieved.

It is without doubt that Raise Boring machinery and its uses have created a buoyant and extremely healthy marketplace for its services.

In addition, the raise boring machines are classified into different types and the characteristics of each type are described within the article. The components of a raise boring machine including the drill rig, the drill string and the auxiliary system. Based on the analysis of the raise boring method, the rock mechanics problems during the raise boring process are put forward, including rock fragmentation, removal of cuttings, shaft wall stability, and borehole deviation control. Finally, the development trends of raise boring technology are described as follows:

- (i) improvement of rock-breaking modes to raise drilling efficiency.
- (ii) development of an intelligent control technique.
- (iii) development of technology and equipment for nonlinear raise boring.

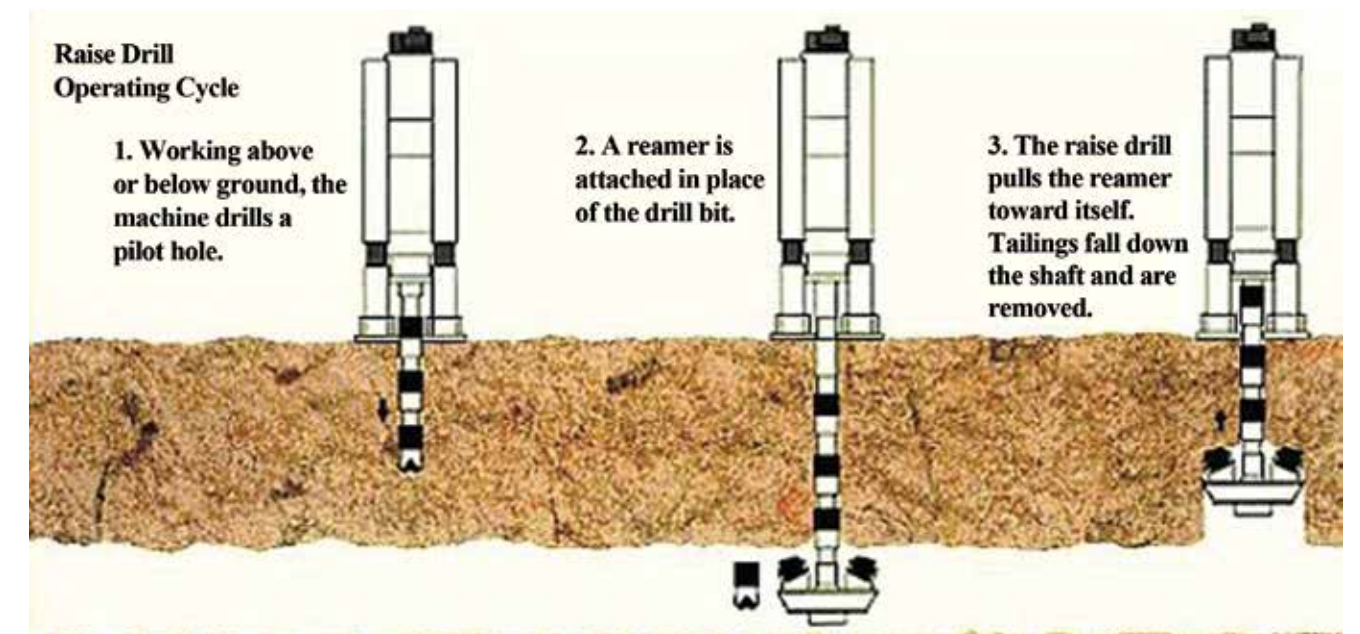
According to the site-specific conditions of most mines, most mineral resources need to be exploited by shaft access mines. As tunnels enter into the ore body, vertical and inclined shafts are constructed from the surface to the desired depth. When the shaft excavation reaches the designed mining level, some horizontal roadways for transportation, ventilation and pedestrian access to the ore body can then be driven. According to the distribution characteristics of the ore body, a variety of shafts should be constructed, such as blind vertical or inclined shafts connecting with ore body at different levels, ore bins storing minerals, ore passes for slipping minerals to the collection level, etc. There is no outlet on the ground for these underground shafts, and due to the dimensions of the shafts, drilling equipment and support facilities are restricted or forbidden in a narrow space.



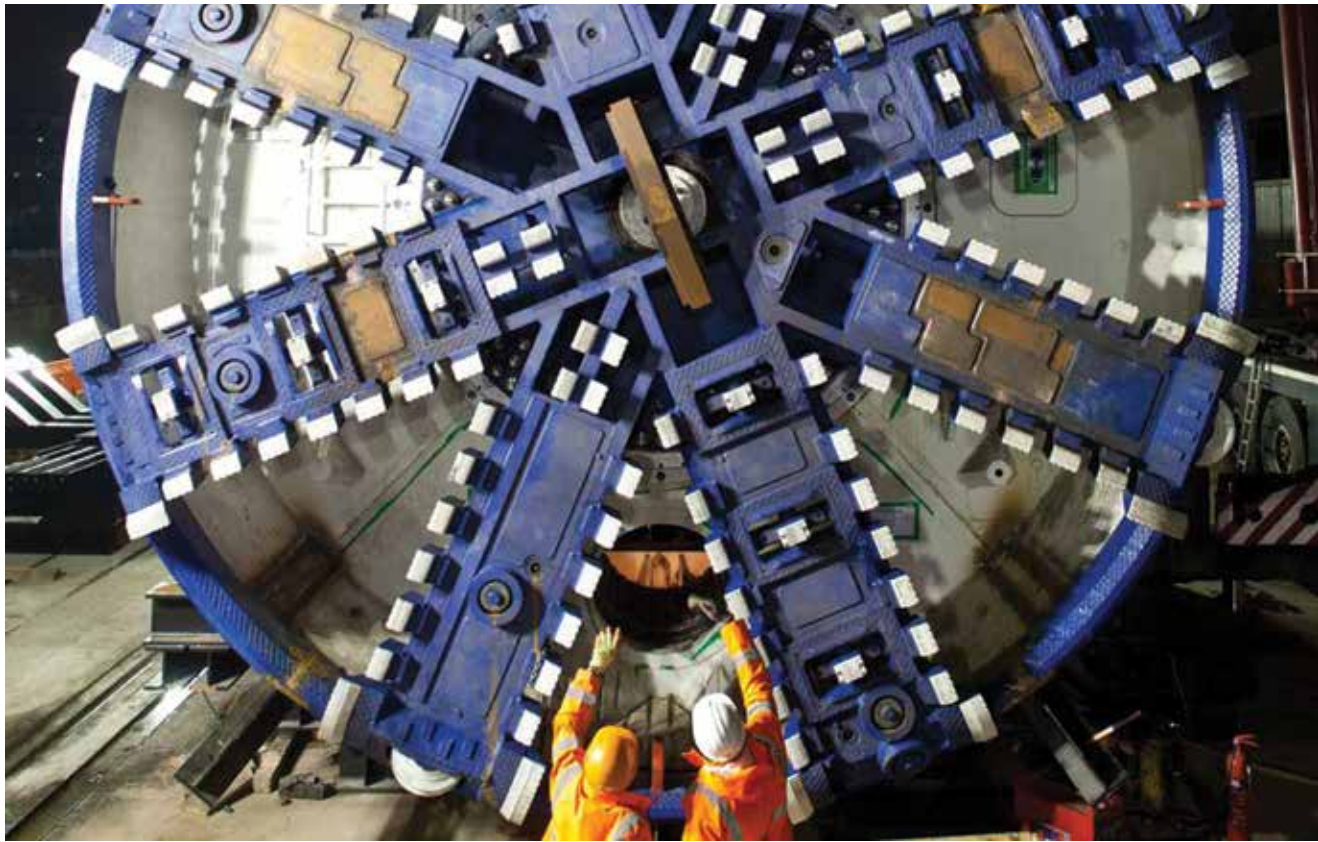
Therefore, the reverse sinking method, called the raise boring method, is generally used on site. The raise boring method is suitable for production of vertical or inclined shafts from bottom to top in underground mining operations. Generally, a small-diameter hole, called pilot hole, is first drilled, through which the cuttings fall to the lower level. The raise is a type of excavation that can be constructed by the raise boring method. Raise boring is very important in the mining industry, and is also applied to other underground engineering projects, such as water conduits, air shafts, elevator hoist-ways and cable shafts in hydro-power stations and pumped-storage power stations to name a few.

According to industry and construction practices, there are a variety of reverse sinking construction processes. In the past, due to factors like complex formations, weak self-supporting ability of rock, and harmful gases in coal mines, the wood-supported raise method, also called conventional raise mining, was generally used in the coal industry in China. With this method, workers first build

cross-bracing, ladders and platforms from bottom to top, and then drilling, charging and blasting operations are carried out on the platform. After ventilation, loading and scaling, the next blasting cycle starts, and wood is used as support structures to maintain the stability of roadways. The creeping cage method was generally used in the hydropower industry, and was adopted as transportation equipment for workers and working platforms for excavation operations. The hanging cage method was generally used in metal and nonmetal mines. In these raise boring methods, workers need to enter the working face to apply operations of drilling, charging, blasting and supporting and as a result are liable to be affected by water gushing, harmful gases, rock caving and so on, leading to frequent accidents and low work efficiency. To solve the above safety problems of construction, the deep-hole blasting method was developed. A set of parallel boreholes is drilled along the axis of the shaft at the top by the drill rig, charging is carried out from the upper level, and blasting is applied piecewise from bottom to top. The accuracy of drilling holes limits the construction depth of







this method. Therefore, new methods and equipment were needed. In 1850, a percussion-type drilling machine was first used to drill a small diameter shaft. In the 1930s, the rotary rig was adopted for drilling vertical shafts, and the tunnel boring machine (TBM) was applied in tunnelling gradually. In the 1950s, miners applied the rock-breaking mechanism of shaft drilling machines and TBMs to raise boring, and gradually the modern raise boring machines

were developed. However, raises constructed by raise boring machines have small diameters and often act as pilot holes. Thus, other methods are needed to ream the pilot holes by raise boring machines to the designed sections. This study presents the concept of shaft excavation by raise boring machines. To this end, the large raise boring machine, drilling process, rock breaking and shaft wall stability during raise boring should be studied.

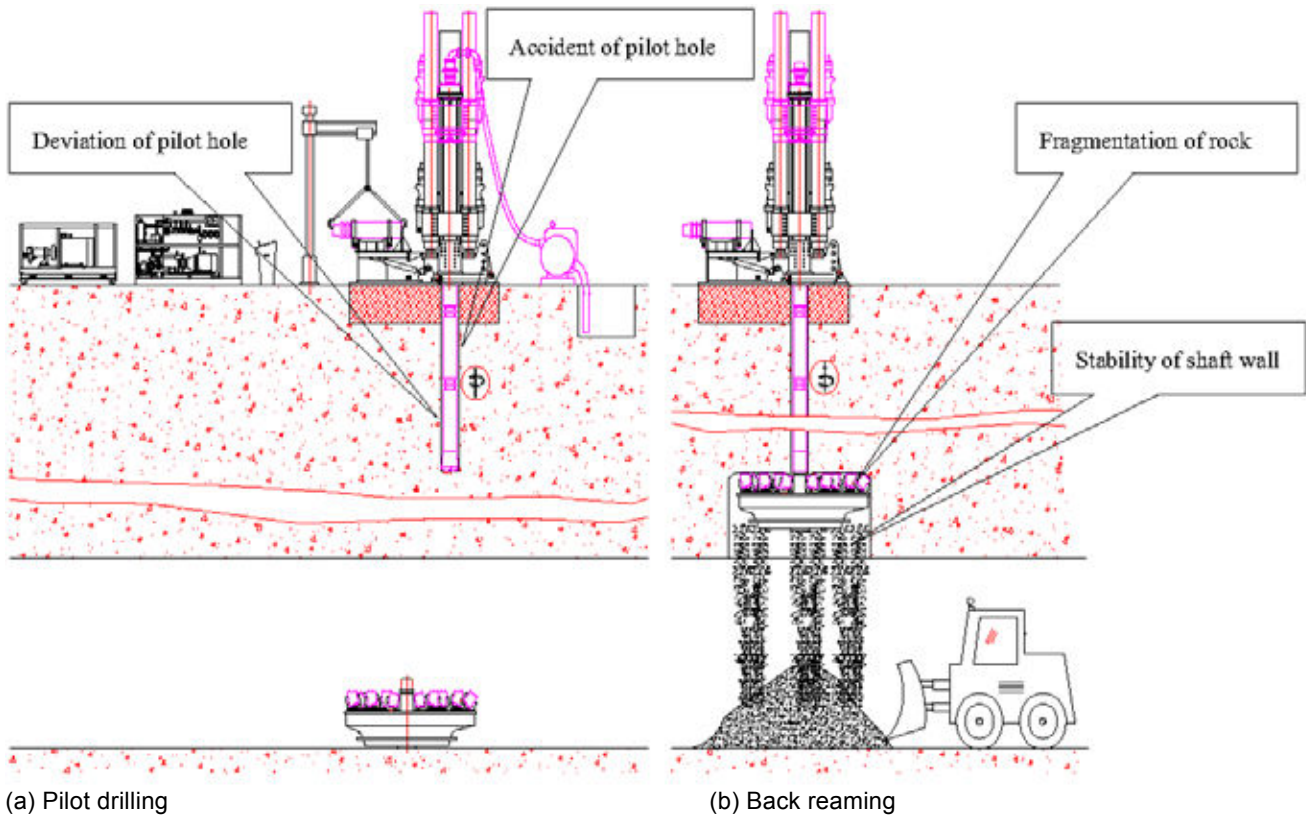


Figure 1: Raise boring method and correlated rock mechanics problems.

Table 1: Main functions and components of raise boring machine.

Component	Function and purpose	Main structure
<b>Drill rig</b>		
Frame, rotation and auxiliary operating system of the raise boring machine	Provide thrust, tension and torque for rock breaking; sustain reactive tension and torque in the drilling process; transmit the reaction force to the rig base; achieve the purpose of dismantle or connect the drill string	<i>Propulsion and guiding parts</i>  Propulsion: hydro-cylinder type, chain type, gear rack type Guiding: frame type, cylindrical structure type, rectangular structure type  <i>Rotation and driving parts</i>  Hydraulic motor (high-speed motor with planetary gear reducer, low-speed motor with multi-stage reducer), frequency conversion motor, DC motor, AC motor, etc.
Power (driving) system	Provide power for propulsion, rotation, auxiliary functions of the drill rig using high-pressure oil and controllable electricity	High-pressure oil: motor or diesel engine driven hydraulic pump Electricity: inverter, DC/AC controller
Control system	Control and regulate the power to achieve the function parameters and auxiliary operations of drill rig	Hydraulic valves control, switches control and computer-aided control
<b>Drill string</b>		
Drill pipe for pilot holes	Drill pilot holes and ensure the drilling accuracy	The drill pipe for pilot holes is made of round steel processed by cylindrical grinder
Common drill pipe	Transmit thrust, tension, torque, etc., for rock breaking	The drill pipe or its upset end is made of round steel
Special-shaped joint	Fit nonstandard thread of drill bit	The special-shaped joint is made of round steel
Pilot bit	Break rocks during the pilot drilling	Tricone drill bit, diamond drill bit
Reamer head	Crush rocks during back reaming	Spherical, conical, flat structure, integral structure, assembly structure
Cutter	Mount on the reamer head to directly crush rocks	Disc cutter, roller cutter (conical button, spherical button, composite button)
Stabilizer	Support the drill string	Spiral, straight, reamed hole and other types
<b>Auxiliary system</b>		
Circulation system	Remove cuttings, cool down drill string and stabilize the hole wall during pilot drilling	Centrifugal pumps, submersible pumps, mud pumps, high-pressure gas, mud, detection system
Cooling system	Cool down the hydraulic oil or electrical components, reamer head and cutter, and reduce dust during drilling	Fan, outer recycle cooling water, internal recycle cooling liquid, recycle cooling pump, water supply within drill pipe, water supply in annular space, nozzle spray of reamer head
Cutting removal system	Remove cuttings during back reaming	Scraper loader, rock loader, side loader, scraper, rake loading machines, belt conveyor, tramcar, etc.
Quality checking of boreholes	Detect and correct borehole deviation and situation during pilot drilling	Inclinometer, screw power drill string under the shaft, signal transmission, underground TV, rotary directional drilling system
Water supply	Provide water for pilot drilling, cooling, and mud mixing, etc. during raise boring	Pipes, pumps, etc.
Power supply	Provide power for electric-driven equipment	Control switches, etc.

DRILLING PROCESS AND CONSTITUTION OF RAISE BORING MACHINES

The raise boring method is a way to excavate shaft by back reaming the pilot hole using drill rigs. The drill rig plays a significant role in underground engineering, such as mineral exploration and blasting. For rotary type of drill rigs, the rotational torque and axial force are exerted to drill bit (called pilot hole drill bit for raise boring machines) along the drill pipe to create a circular hole. Generally, the cuttings are removed from the hole with the aid of flushing medium (as shown in Figure 1a). The construction process of the pilot hole by raise boring machines is the same as that by conventional drilling machines except the back reaming process introduced in the raise boring method. When the pilot hole breaks through into the lower level, the drill bit is removed and replaced with

a large-diameter reaming head. The reamer is rotated and pulled back toward the drilling unit, and through this way a large-diameter shaft is formed (Figure 1b). A complete set of raise boring machine includes drill rig, drill string and auxiliary system, as shown in Table 1.

CLASSIFICATION OF RAISE BORING MACHINES

Different from the conventional drilling machines, the cuttings usually fall down to the lower level by gravity during raise boring, which is the common characteristic for all types of raise boring machines. The above-mentioned conventional raise borer is only one type of raise boring machine, and the drilling process involves two steps, i.e. pilot drilling and back reaming. In fact, there are many types of raise boring machines. For example, they



can be classified into box type, frame type and column type according to the structure of the drilling frame; chain type and cylinder type according to the propulsion mode; motor-driven type and hydraulic motor-driven type according to the rotational power source. However, these classifications are not based on the essence of the raise boring machine. The raise boring machines can be classified into two types according to the back reaming process, i.e. upward reaming type and downward reaming type. **Table 2** briefly lists the characteristics of two types of raise boring machines. According to the reaming direction of the raise boring machine, the drilling process can be classified into two categories, i.e. the upward reaming method (**Figure 2a**) and the downward reaming method (**Figure 2b**). The following conclusions can be drawn by comparing the two reaming methods:

1. In the downward reaming method, the cuttings fall down through the annulus between the drill pipe and the hole wall to the lower level. The cuttings shattered by the cutter in different positions on the reamer head converge at the center of the head and are repeatedly broken by other cutters. In the upward reaming method, however, the cuttings usually fall down by gravity, and are rarely repeatedly broken,

- so its efficiency is higher than the downward reaming method.
2. In the downward reaming method, the pilot hole is the passage of the drill string and cuttings, thus the falling down of the cuttings can damage the drill string. In the upward reaming method, however, the pilot hole only serves as the passage of the drill string which needs small-diameter hole, so the drilling speed of the pilot hole is fast.
3. It is easier to drill pilot hole and control hole deviation by upward reaming than by downward reaming. In the downward reaming method, since the drill string is under compression during pilot drilling and easily bent, the quality of the hole is difficult to control, and the drilling depth is limited.
4. In the upward reaming method, since the workers operate the drilling machine in the upper level, the working condition is safer than that of the downward reaming method. In the downward reaming method, since the cuttings removal and drilling operations are carried out in the lower level, the working condition is poor.

Table 2: Comparison between two types of raise boring machines.

Raise boring machine	Position of drilling machine	Drilling direction of pilot hole	Position of replacing reamer head	Reaming direction	Reaming mode	Drilling depth (m)	Borehole diameter (m)	Cuttings removal	Applicable condition	Advantage	Disadvantage
Downward reaming type	Lower level	From bottom to top	Upper level	From top to bottom	Multi-step reaming	<200	1.2	Cuttings during reaming process fall down to the lower level and are mucked out by loaders	There are roadways both in upper and lower levels	Weight of the drill string is helpful in rock breaking, thus the energy is saved. This kind of machine has low power, relative small size and weight	Cuttings removal and drilling operation can affect each other. Hole diameter of each reaming is small, and rocks are repeatedly broken. Drilling efficiency is low. Reaming should be conducted for many times, and speed is low. Accuracy of borehole is hard to ensure
Upward reaming type	Upper level	From top to bottom	Lower level	From bottom to top	One-step reaming	1000 (maximum 1260)	7		There are roadways both in upper and lower levels	Drilling operation and cutting removal are separately carried out on two different levels. Working condition is good. Influence of geological conditions is little. Perpendicularity error of borehole is easy to control	It is difficult to drill pilot hole, and many auxiliary equipment is needed
	Lower level	From bottom to top	Lower level		One-step reaming	<100	1		There is a roadway only in lower level	It can be used when there is no roadway or production system in the upper level	The power of drill machine is high. Cuttings removal and drilling operation can affect each other
	Upper level	No pilot hole	Lower level		One-step reaming	<100	1				



(a)



(b)

Figure 2: Photos of two types of reaming method: (a) Upward reaming; and (b) Downward reaming.

MAIN TECHNICAL PROBLEMS DURING RAISE BORING

The raise boring machine has completely changed the working conditions in raise construction, and workers operate machines far away from the dangerous working face. All drilling processes are achieved by the raise boring machine, which lays a good foundation for automatic and unmanned drilling technology. In the past decade, great achievements in raise boring technology and equipment research have been made in China. The diameter and depth of drilling holes reach 5 m and 600 m, respectively, and the application of the raise boring machine is extending to other fields gradually. The progress in raise boring technology needs to address many important issues about basic theory and key equipment of raise boring machine. According to the drilling process of the conventional raise boring machine, a series of rock mechanics problems should be concerned, including stability of hole wall, interaction of drill string and rocks, drilling trajectory control of pilot hole, etc.

Pilot drilling

Pilot drilling is a process of drilling a pilot hole in a small diameter along the axis of shaft (**Figure 4**). When the pilot hole breaks through into the lower level, the roller bit is removed and replaced with a reaming head. The reamer is rotated and pulled back toward the drilling unit, and eventually the shaft is formed. The following requirements should be satisfied for pilot hole in raise boring:

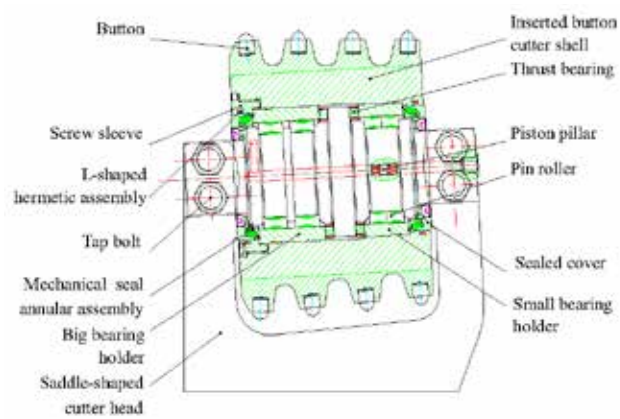


Figure 3: Sketch of rock-breaking cutter.

1. The axis of pilot hole should be linear as much as possible and its curvature cannot change too large.
2. The maximum distance from axis of pilot hole to shaft axis must be kept within the engineering allowance, i.e. the deviation rate of the pilot hole should be minimized.
3. In the drilling process, accidents must be avoided, and the finished pilot hole should be smooth and stable.

Rock breaking in pilot drilling

During pilot drilling, rocks are separated from the rock body by tricone roller bit. The mechanism of rock breaking by the drill bit has been researched extensively in petroleum engineering and thus can be used in the raise boring. Different from petroleum drilling, raise boring aims to detect rock properties and geological structures in advance, and to provide a reference for selection of reamer and supporting method. On the basis of regression equation of drilling speed, weight on bit, rotational speed and torque during pilot drilling through different strata, rock drillability classification and relationship between back reaming parameters and pilot drilling parameters should be studied.

Cyclic cuttings removal in pilot drilling

The flushing media used for cuttings removal include mud, water, compressed air, etc. Introduced through the center of the drill pipe, the flushing media are sprayed out through the tricone bit nozzle with the aid of the pump. The rock broken by the cutter is separated from the hole bottom, and removed out of the borehole along the annulus between the drill pipe and hole wall. The basic condition for effective cuttings removal is that the speed of flushing media is higher than the sedimentation speed of cuttings in the flushing media. As a typical flushing media, the mud has good suspension properties, and it also can help to prevent the collapse of hole wall. However, the sudden loss of mud pressure when the hole breaks through into the lower level can result in hole collapse and drill devices buried in unstable strata. Therefore, water is often used instead of mud to remove cuttings from pilot hole. With the aid of water flushing, the unstable strata can be easily explored and addressed to prevent the accident after hole drilling. Compressed air can achieve efficient cuttings removal in the condition that the strata are relatively stable and hard, with abundant cracks and small caves, but the leakage of flushing fluid is serious. Thus the flushing medium and flow in different strata and reasonable parameters such



as pressure need to be studied. According to different flushing media and cuttings flow, the risk of strata should be determined to prevent drilling accidents.

#### Deviation control of pilot hole

Deviation of pilot hole is that the center line of pilot hole does not coincide with the planned shaft axis. Deviation rate of pilot hole is a ratio of raise length to the maximum deviation. Deviation of pilot hole is generally caused by anisotropy of strata, machining accuracy of drilling devices, artificial control, etc. In pilot drilling, rock is broken by drill bit. The drill bit is connected with stable drill pipe and ordinary drill pipe to form a drilling string to stabilize the drilling process and to reduce its impact on the borehole deviation. However, the machining cannot ensure that the axes of all drill pipes are connected in a line. Drilling tends to deviate from the designed direction, affected by the drilling pressure. Underground stratum is a typical anisotropic body which can produce uneven hole bottom and additional moment, making drilling deviate from the designed drilling direction. The interaction between the drill string and hole wall can also bring in stress changes of drill string and influence its normal operation. The adaptability of designed drilling schemes to the mechanics parameters of different strata, including drilling pressure, rotational speed, and torque, will also cause deviation of pilot hole. Therefore, the influences of physico-mechanical properties and anisotropy of strata, interaction of drill string and hole wall, and drilling parameters on deviation of pilot hole need to be studied, and automatic-correction drill string by terrestrial magnetism should also be developed.

#### Pilot hole stability and accident control

When the deviation of pilot hole is beyond the engineering allowance, the pilot hole cannot be used anymore and has to be abandoned. In addition to this serious engineering accident, there are many other drilling accidents, such as drill string loss and pilot hole abandonment due to

leakage of flushing fluid, hole shrinkage and collapse, and drill string burying induced by unfavorable geological conditions. The drill string is generally more expensive than the drill rig, thus the damage of drill string will cause greater economic losses. For this reason, cyclic cuttings removal, drilling parameters changes, vibration of drill rig and other factors should be studied to determine strata conditions and early-warn accidents, and reinforcement and modification technology of strata in advance should be researched to prevent wall collapse of shaft with large section and no support in back reaming.

#### Back reaming

##### Efficient rock breaking

In back reaming, the raise boring machine drives the drill pipe rotation, and energy is transferred to the reamer head along the drill pipe. Then the cutter is driven to crush down the rocks, and the cuttings fall down by gravity to the lower level, where they are mucked out using loaders. As shown in **Figure 3**, the cutter is composed of drill button, cutter shell, sealed bearing, saddle, etc. Two cutters are in a group and laid symmetrically to finish rock breaking. As shown in **Figure 4**, the main technical parameters of the cutter include generatrix length, cone angle, diameter of large end, button spacing and row spacing, etc. The button parameters include button shape, diameters, and so on. During back reaming process of raise boring machine, the reamer exerts certain force on the cutter in the drilling direction until the cutter presses into the rock, and the rock fails when the deformation is beyond its elastic limit. Meanwhile, the cutter rotates under the combined action of rocks and rotating reamer head, and the cutter buttons extrude and scrape the rock, bringing in button marks on it. These marks in similar size and depth cause gradually separating of rock fragment from rock body and formation of rock breaking with circular section, which can meet the project requirements. Therefore, mechanism of rock breaking by cutter, rock drillability, structure and shape of cutter, material and structure of

cutter button, wear resistance, arrangement of cutters on the head, spatial arrangement of the head to satisfy efficient cuttings removal need to be studied.

#### Stability of shaft wall

Although the back reaming of raise boring machine has minor disturbance to shaft wall, a variety of factors that affect stability of shaft wall still exist.

1. Stratigraphic conditions. When the shaft is constructed in an unstable formation, the formed shaft wall after back reaming cannot support its stability, and phenomena like rock expansion and crushing by contacting with water often occur and will cause partial collapse, rib spalling, caving of the shaft.
2. Gushing water and cooling water in strata. When the pilot hole breaks through into the lower level, the flushing water leaks out, and the mud pressure on hole wall disappears, making the water contained in strata flush into pilot hole. As the exposed area of rock increases during back reaming, the water inflow grows. In the back reaming process, heat produced by breaking rock results in a sharp rise in the temperature of the cutter. Thus a nozzle is set in the reamer head to spray water to cool the cutter down. Meanwhile, the water mist can clean dust produced in rock breaking to reduce the influence of dust on the lower production system. The gushing water and cooling water have adverse effects on strata stability, for example, they will flush cement of shaft wall rock, reduce cohesion and internal friction coefficient of rock, and increase rock instability risk.
3. Concentration and redistribution of stress. In the process of raise boring, the shaft gradually forms, and the original rock stress distribution gradually changes. Generally, stress concentration occurs on the pilot hole wall, shaft wall and interface between cutter and rock. In fractured strata, once the broken condition is satisfied, partial collapse will occur.
4. Prolonged exposure of shaft wall. The exposure time varies in different parts of shaft wall using raise boring method. The exposure time of the lower shaft wall is the longest, and it includes the time of back reaming, the time from the dismantling of the raise boring machine to the installation of support and lifting equipment, and the time of temporary support from top to bottom. As to the raise boring shaft with 400 m in depth and 5 m in diameter, back reaming generally lasts for 2-3 months, dismantling and mounting of lifting equipment and hanging scaffold for a week, and temporary support of anchoring and shotcreting generally for 1.5-2 months. Thus the exposure time reaches 110-160 d. The exposure time of shaft wall reduces gradually from bottom to top, and the influence of exposure time on stability of shaft wall needs to be studied.

engineering. In these projects, the boring machines drill through rocks characterized with different properties. In coal mines, coal is one of the major types of sedimentary rocks with low uniaxial compression strength (UCS) (<120 MPa). The drilling depth in coal mines can reach 600 m, and the maximum diameter of back reaming reaches 5 m. The boring inclination ranges from 50° to 90°, and the maximum rate of back reaming is 0.8 m/h. In hydropower projects and other underground engineering, the rock masses are mainly composed of igneous rocks with high UCS of 120-200 MPa. The drilling depth can reach 600 m, and the maximum diameter of back reaming reaches 3.5 m. The boring inclination ranges from 40° to 90°, and the maximum rate of back reaming is 0.5 m/h.

#### Main technical parameters

1. Drilling pressure,  $P_r$

The reamer head of 5 m in diameter ( $D_r$ ) contains 30 cutters on it, and the 3.5 m diameter head contains 18 cutters (**Figure 5**). When drilling is performed in the rocks with UCS less than 120 MPa, the pressure on cutters for breaking rocks should be approximately 35 kN, thus the drilling pressure for reamer head of 5 m in diameter is 1050 kN. When the UCS of rocks reaches 200 MPa, the pressure exerted on cutters should reach 80 kN to meet the target drilling rate, thus drilling pressure for reamer head of 3.5 m in diameter needs to be 1440 kN.

2. Rotational speed,  $n_r$

In order to achieve high efficiency of rock breaking and low wear of cutter buttons, the time of cutter buttons in contact with rocks should be 0.02-0.03 s, and correspondingly the linear velocity ( $V_c$ ) of side cutters should be controlled at 0.7-1.0 m/s. Through calculation,  $n_r = 60V_c/\pi D_r = 2.67-3.8$  r/min, thus the designed maximum rotational speed of raise boring machine is 5 r/min.

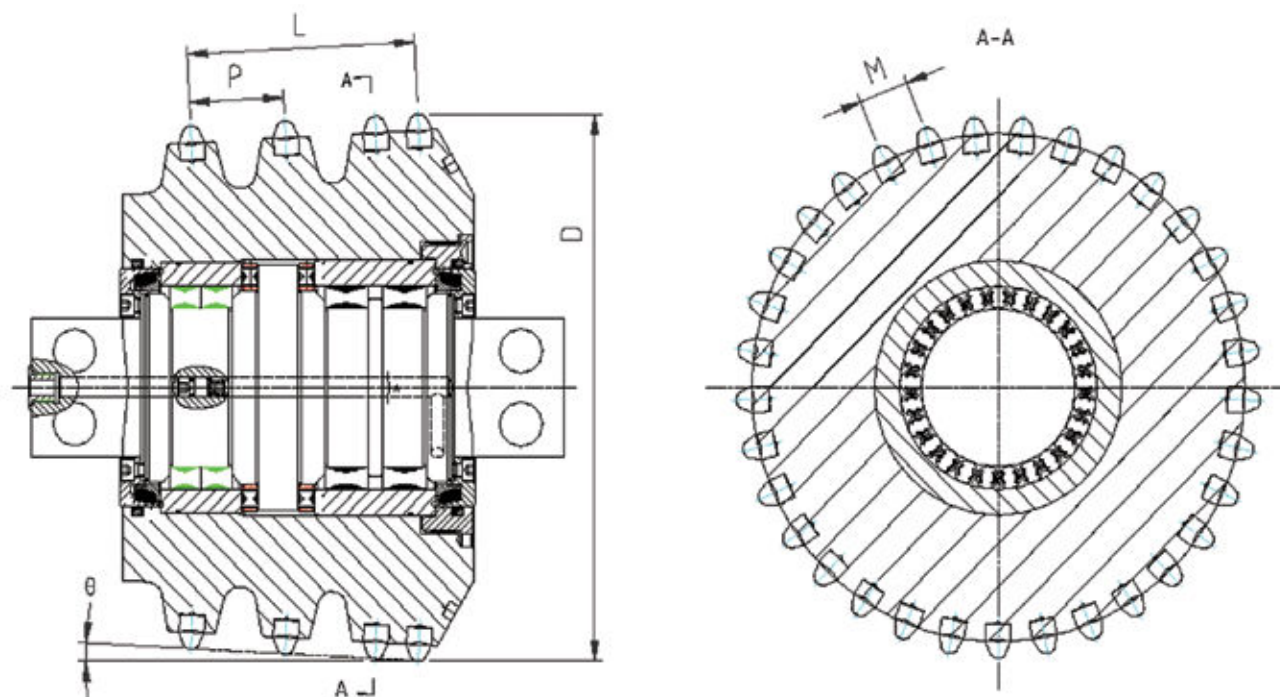
3. Torque,  $M_s$

Based on the drilling rate and rotational speed, the drilling depth ( $h_r$ ) in each round is 1.6-2.7 mm. In addition to the drilling depth in each round (or the drilling rate), the maximum torque of rock breaking is also related with the diameter of the reamer head and the friction coefficient of the cutter bearing. In rock breaking, the cutters require energy to separate rock from rock bodies, and the cutter bearing and friction between reamer head and rock can also consume some energy. Without considering some other minor factors, the torque can be calculated as

$$M_s = \frac{K_r \pi (D_r^2 - D_p^2) h_r}{4}$$

where  $K_r$  is the required energy to break unit volume of rock by cutters, and it contains energy loss. The consumed energy in the laboratory experiment of UCS is low, and the common consumption value is  $5 \times 10^7 - 9 \times 10^7$  J/m<sup>3</sup>.  $D_p$  is the diameter of the pilot hole.

The required torque for different drilling rates ranges from 156 kN m to 264 kN m. Considering other accident treatments, the torque of the raise boring machine is 300 kN m.



**Figure 4:** Basic parameters of cutter.  $L$  – generatrix length;  $P$  – row spacing;  $D$  – diameter of large end of cutter;  $M$  – button spacing;  $\theta$  – cone angle.

#### TECHNOLOGY AND EQUIPMENT OF RAISE BORING

##### Application conditions and main technical parameters of raise boring machines

##### Application conditions

The study of raise boring technology was initiated from the construction of air shafts in coal mines, and then it was conducted in hydropower projects and other underground



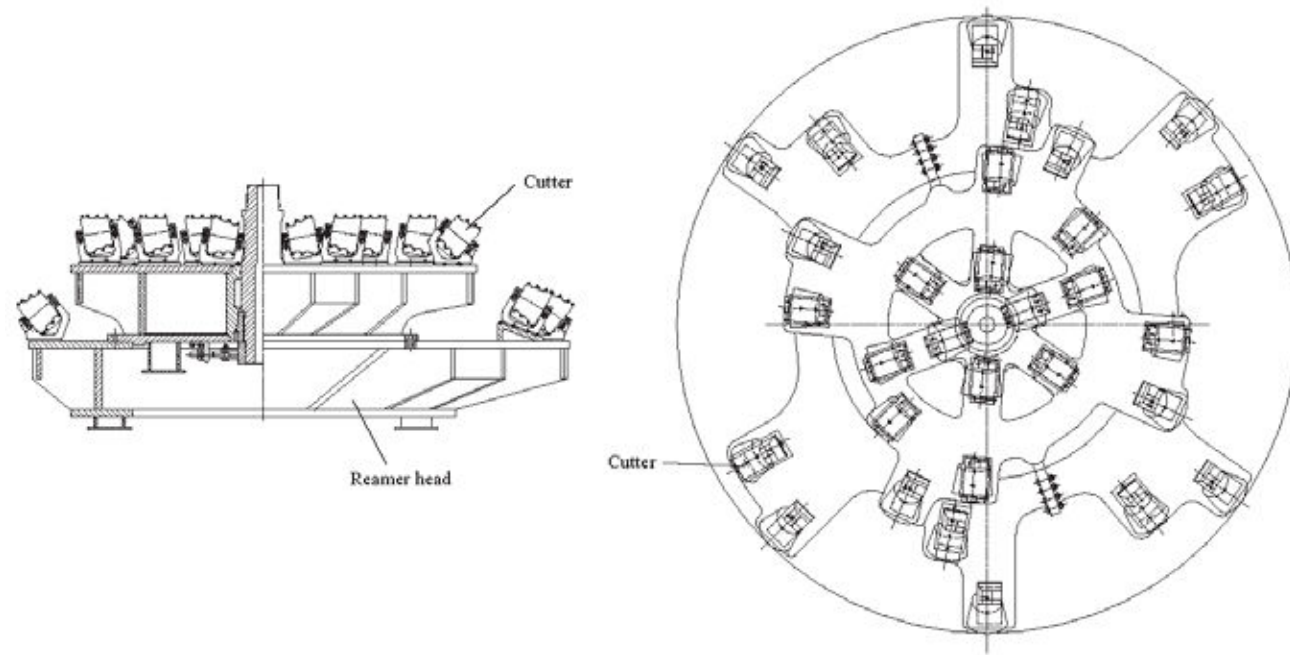


Figure 5: Structure of reamer head of the raise boring machine for shafts of 5 m in diameter.

#### Other parameters

Based on the rotational speed, torque, and drilling pressure, the tension of the raise boring machine is calculated. Considering the total weight (3160 kN) of drill pipe 600 m long (2700 kN), drill bit 5 m in diameter (400 kN), and driving unit (60 kN), the lifting force of the raise boring machine is 4610–4750 kN. Considering the machine's capacity, the tension of raise boring machine is designed to be 6000 kN.

The main technical parameters of the self-developed raise boring machine ZFY5.0/600 for shafts 5 m in diameter are shown in Table 3.

#### Development of raise boring machine for large-diameter shafts

Figure 1 shows the schematic diagram of site application of the self-developed raise boring machine ZFY5.0/600. Considering the capacity improvement of the raise boring machine, there are 4 cylinders, 2 guide posts (Figure 6) and 4 motors (Figure 7) in the drill rig. The main force-bearing components are bolted rigidly. The adjustable angle of the machine body is not less than 30°. The electrohydraulic control system is adopted in power and control system to ensure the flexibility, intelligence and safety of the drilling machine. The drill pipe is 1.5 m in length with 1:8 cone thread. The reamer head is composed of removable segments (as shown in Figure 6), facilitating underground transportation and installation.

#### Case illustration

The auxiliary ventilation shaft in Baoxin coal mine of Lanhua Coal Industry Group in Guxian, Shanxi, China is 4.7 m in net diameter and 482.2 m in depth. The shaft passes through the rock strata of upper Shihezi group, lower Shihezi group, Shanxi group, and Taiyuan group, with UCS less than 100 MPa. The self-developed raise boring machine ZFY5.0/600 is adopted in this project. In order to ensure the stability of the shaft wall and safe construction, risk assessment should be first performed using detailed geological exploration data, including rock composition, physico-mechanical properties of rocks, geologic structure, development of fissures and bedding, and underground water situation in strata. Secondly, pilot drilling should be considered. Based on the investigation of the exposed rock, leakage of drilling mud and drilling parameters, the stability of the shaft wall after back reaming can be determined. Through analyzing geologic exploration data, the upper unstable strata may lead to the collapse of the borehole by water flushing during drilling process, thus partial excavation and shotcreting are conducted (Figure 8). The unstable strata are removed from top to bottom and supported temporarily, and the stable strata are reinforced using low-grade concrete. As the concrete reaches certain strength, the raise boring machine is installed and the drilling starts. The drilling site of the raise boring machine is shown in Figure 9. The pilot drilling of the Baoxin coal mine took 25 d from March 15 to April 10, 2012, within which 215 h is consumed for drilling. The finished pilot hole is 350 mm in diameter and 482.2

Table 3: Main technical parameters of the self-developed raise boring machine ZFY5.0/600.

Basic parameters					Parameters of pilot drilling			Parameters of back reaming				Other parameters	
Diameter of pilot hole (mm)	Diameter of finished shaft (m)	Drilling depth (m)	Drilling angle (°)	UCS of rock (MPa)	Rotational speed (rpm)	Thrust (kN)	Rated torque (kN m)	Rotational speed (rpm)	Rated tension (kN)	Rated torque (kN m)	Maximum torque (kN m)	Mass of drill rig (kg)	Power of drill rig (kW)
350	5	600	60–90	120	0–18	1300	92	2–5	6000	300	450	25,200	284.7

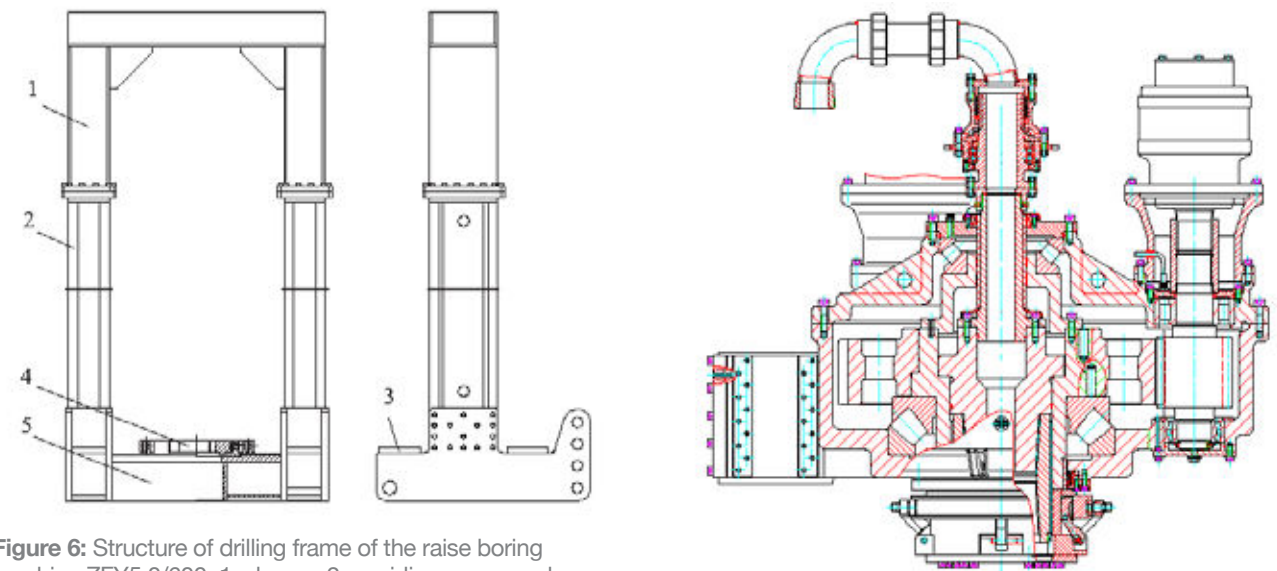


Figure 6: Structure of drilling frame of the raise boring machine ZFY5.0/600. 1 – beam; 2 – guiding square columns; 3 – connecting flange of the propulsion cylinder; 4 – flashboard assembly; 5 – base.

Figure 7: Structure of the multi-motor driving unit.

m in depth, with deviation rate less than 0.2%. The back reaming started on April 25, 2012, and ended on June 10, 2012.

After successful application to coal mines, the raise boring machine ZFY5.0/600 has constructed a dozen deep shafts in hard basalt layers with UCS larger than 150 MPa in Baihetan hydropower station, which further tests the capacity of the raise boring machine.

#### DEVELOPMENT TREND OF RAISE BORING TECHNOLOGY

##### Improving rock-breaking method to increase drilling efficiency

The cutter is the key component of raise boring machine to break rocks, and it is also the main consumable material. The energy consumption of cutting is much higher than that of conventional method like blasting. Therefore, efficient and low energy consumption cutter needs to be developed through the improvement of cutter body structure, cutter button structure and the use of new materials. Based on

the physico-mechanical properties of rocks, auxiliary rock breaking technologies, such as high-pressure water jet, microwave vibration and chemical modification, need to be studied to further improve the efficiency of rock breaking and drilling by raise boring machine. With the development of new technologies, such as laser, high-energy particle, and directionally controlled micro-blasting, current full-face rock breaking methods with which all the rocks are broken can be changed. By forming controllable and regularly shaped artificial fissures, rocks can be separated from rock body. In the process of rock breaking, the shaft wall that needs to be stable can be melted and recrystallized, and the rock properties are fully used to solve the problems of breaking rock and preventing rock crushing.

##### Intelligent control technology

With the development of raise boring machinery, it is increasingly used in various fields of underground construction, and it is suitable for all kinds of excavations from horizontal to vertical. Therefore, improving drilling accuracy and ensuring the drilling along the designed

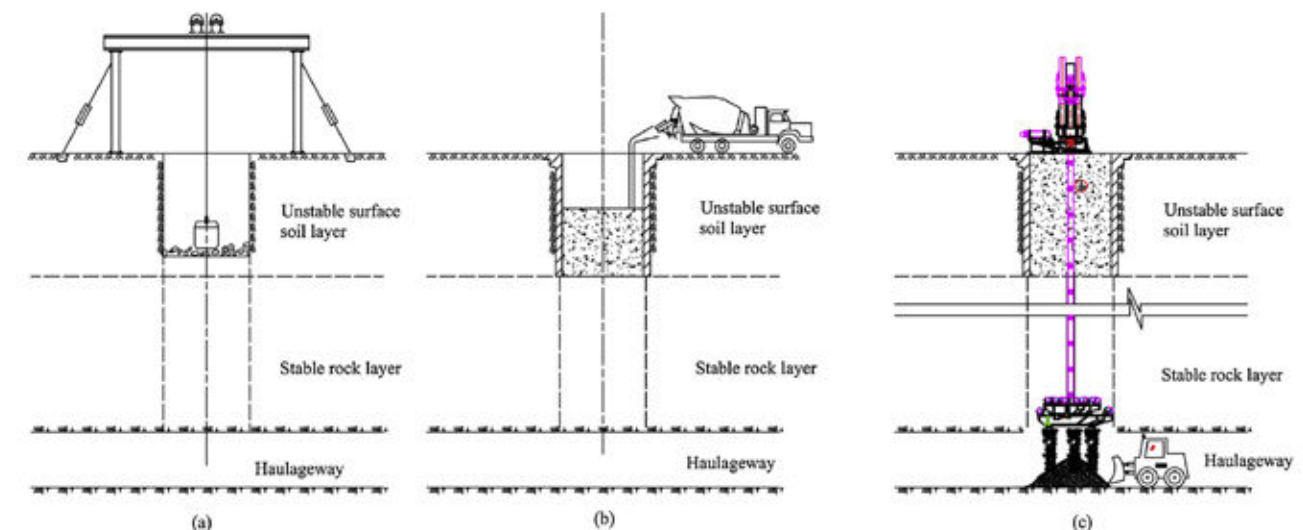


Figure 8: Support process of upper unstable strata. (a) Excavation; (b) Pouring concrete; (c) Back reaming.





Figure 9: Drilling site of raise boring machine.

borehole axis become the most important issues for the raise boring machine. Development of pilot hole drill bit and drill string which can intelligently control the drilling direction is the key to solving the problems. There are some issues to be addressed, such as accurate positioning measurement and signal transmission of drill bit in three-dimensional space, servo-control of drilling direction, structure of small drill bit with these functions, energy supply method of drill bit, etc.

Some projects with nuclear radiation and overflow of harmful gases are not suitable for field operations of workers, and these unfavorable conditions have an adverse impact on equipment performances, or interfere with data communication. Thus the intelligent remote control technology can be applied to efficiently transmit the signals and achieve the unmanned operation of the raise boring machine. In various working conditions, supply, grab and positioning of drill pipes should be intelligently controlled. The raise boring machine has functions of judgment and pre-treatment, and errors can be automatically diagnosed. The drilling work can be carried out by pre-programmed procedures and remote control.

To ensure the stability of the shaft wall, the remote shotcreting technology in conjunction with the raise boring needs to be studied. By timely reinforcement of the surrounding rocks, stability of shaft wall is improved, and accidents during back reaming are reduced. Firstly, intelligent recognition technology of surrounding rocks in the drilling process should be researched. Secondly, remote-controlled shotcreting devices and robot control technology should be studied to achieve intelligent detection of shotcrete layer, intelligent control of shotcreting, and shape control in formed shafts, and thus the following work can be well carried out.

#### Nonlinear drilling

To meet requirements of safe mineral exploitation under different geologic conditions, it is necessary to develop different types of raise boring machines. The raise boring machine with a drill pipe plays an important role in promoting the development of raise boring technology. However, due to the limit of drill pipe stiffness, the present raise boring machines can only drill in a straight direction which is difficult to control. Therefore, raise boring

machinery without drill pipe at early stage of development should be considered when the wire rope was acted as traction and guidance component. With the development of control technology, it is necessary to develop raise boring machines without guidance by the wire rope or so-called "hamster" type of raise boring equipment to exploit nuclear material, gold and other rare minerals along the mineral vein. Thus through tracing the minerals, the raise boring machine can reduce the ore dilution, decrease mining costs and impact on the environment, finally achieving green mining.

#### CONCLUSIONS

The raise boring machine has made great progress in the last several decades. As a type of equipment used in site-specific conditions, the raise boring machine can now be applied to many fields, including coal mines, hydropower stations, transportation, underground building, military engineering and other underground projects, with the maximum excavation diameter gradually increasing. Particularly, the successful development of the raise boring machine ZFY5.0/600 achieves large-diameter shaft construction, whilst former raise boring machines can only drill small-diameter raises. The raise boring machine ZFY5.0/600 constructed a ventilation shaft 5 m in diameter in a coal mine and drilled a dozen deep shafts 3.5 m in diameter in hard basalt at the Baihetan hydropower station. However, many theoretical, mechanical and other technical issues about raise boring machines and the drilling process need to be further studied to solve problems on aspects of drilling efficiency, energy savings, safety, unmanned operation and so forth. Optimization of the rock-breaking method, intelligent control technology, and nonlinear drilling of the raise boring machine need to be further researched and developed. As a reliable mechanized construction method, the raise boring technique is an ideal supplement to traditional shaft construction, and provides an efficient, mechanized construction method. Compared with the conventional drill-and-blast method, mechanized construction methods can greatly reduce the number of operating workers, improve safety in the construction of shafts, reduce injuries of workers and improve working efficiency. Therefore, the development and application of raise boring technology are prospective.



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## Record demand for silver forecast in 2022

The Silver Institute has forecast global silver demand to rise to a record 1.112 billion ounces in 2022 as traditional and green technologies increase its use.

These established and emerging uses in industrial fabrication are expected to rise by 5% this year, while use in jewellery and silverware could rise by 11 and 21% respectively.

The news comes as the Perth Mint announced record silver sales for January, selling 2,387,165 ounces of silver in minted product form.

Perth mint general manager of minted products Neil Vance said the total was the second highest monthly total, behind September 2015 when 3,349,557 ounces were sold.

"This January we released our 2022 Australian Koala

silver bullion coin series and also took first orders for our one kilo Lunar Tiger coins," Vance said.

"Both releases are globally popular and contributed heavily to an especially pleasing month, which also reflected a build-up of demand during the Christmas and New Year period at the end of 2021."

The uptake of solar panels and their components was seen as a big factor in silver's continued strength in 2022, according to the Silver Institute.

"The outlook for silver's use in the photovoltaic (PV) industry remains bright. Government commitments to carbon neutrality have resulted in a rapid expansion of green energy projects," the Institute stated.

"As a result, even with ongoing efforts to reduce

silver loadings, record PV installations are expected to lift silver demand in this segment to an all-time high in 2022."

The news comes at a good time for Alien Metals, which recently discovered bonanza silver grades of 36 kilograms per tonne at its Elizabeth Hill silver mine in Western Australia.

The drilling results far exceeded expectations of the long dormant mine, which once averaged grades of 2195 grams of silver per tonne (g/t) before

it was mothballed in 2000.

While a restart of Elizabeth Hill remains uncertain, the Silver Institute projected a rise of 7% in global silver supply to a six-year high of 1.092 billion ounces in 2022.

Some Australian mines contributing to this figure will be 29 Metals' Golden Grove copper-gold-zinc-silver mine in WA; South32's Cannington silver-lead mine in Queensland; and Glencore's Mount Isa zinc-lead-silver mine, also in Queensland.



## International Fair EXPO KATOWICE (MTGPEiH) Katowice Mining Expo Katowice, Poland 6-9 September 2022

The International EXPO KATOWICE (MTGPEiH) Fair is a meeting place for business and science. The energy and electricity industry has an excellent space to present innovative devices and technologies. An international fair is a great opportunity to establish cooperation between service providers, concerns, including the largest energy concerns, specialists, design offices, and end recipients. The event is also accompanied by B2B meetings and conferences with leading representatives of the power sector, competitions for young engineers and scientific seminars. We listen and adapt to create "the perfect atmosphere for meetings to talk about the direction of development of this strategic industry".

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## ARDVARC autonomous technology allows for superior drill control

FLANDERS' ARDVARC control system combines PLC control with Windows-based computer applications to co-ordinate control of any electric, or electric-over hydraulically controlled OEM drill rig.

During the drill cycle, the PLC has primary responsibility for control of the drill. Drilling functions are monitored at twenty-millisecond intervals, and control updates are made as ground conditions change to ensure the drill is penetrating the ground at optimal performance levels, while also ensuring the drill is not being damaged.

The drilling sequence controls these primary phases of the drill process:

- levelling – the drill is auto-levelled to within 0.1°, ensuring accurate end-of-hole positioning
- ground detection – once levelled, the drill bit is lowered to determine accurate ground elevation, which is compared with the end-of-hole designed elevation to determine how deep to drill
- hole collaring – ensures good hole quality once the drill leaves the hole
- drilling – bit parameters are monitored during drilling to ensure the drill is properly penetrating the ground, including vibration, rotary torque, hoist force on the bit, air pressure, rotary RPM,

penetration rate and head position. Changes in feedback indicate changes in ground conditions, which in turn initiate control algorithms designed to deal with adverse conditions.

- FLANDERS has patents pending for its ground hardness profile algorithms
- quality checks – once the bit has reached the target elevation, the control system initiates a quality check that measures the hole and monitors any fall-back material as the bit is retracted
- retraction – once the hole is drilled and measured, the control system retracts the drill bit from the ground; and
- reset – the drill retracts the levelling jacks and indicates that it is ready for the propel cycle to begin. In the fully automated version, the drill starts to propel from one hole to the next.

The windows PC displays drill hole targets in the form of black cross marks on the GPS map. Once drilled, these crosses turn blue. If the mine has multiple ARDVARC systems in its fleet, a hole drilled by a different drill will be displayed as a red cross, letting the operators of every drill know which holes have and have not yet been drilled.

"This is a very important

feature of the ARDVARC product," said FLANDERS director of automation Josh Goodwin.

"This function is available regardless of the level of automation at the mine."

In addition to hole locations, the HazTech system allows obstacles and hazards to also be displayed on the GPS map.

FLANDERS says that regardless of level of automation selected, ARDVARC collects highly reliable data in a SQL table that denotes production along with engine health.

This data is communicated in real-time via wireless Ethernet, either using the mine site's existing infrastructure or a FLANDERS-provided wireless network, to a central server where it is immediately available for reporting.

Both current and historical data is then web-served for multiple clients to view at any time without disrupting the operators.

New data collection points are generated every six months during software updates, and include: availability, utilisation, and average fuel consumption.

### ARDVARC is available in three levels of automation:

Base system: *Intelli-Rig* is a 100% manually controlled system utilises Allen-Bradley Control Logix automation controllers to monitor digital

and analogue input/output (IO) signals, collected and propagated over a drill wide DeviceNet IO network.

The signals set up drill permissive conditions, enabling the drill to protect itself from component failure and operator abuse. The control system is connected to operator input mechanisms such as joysticks and pushbuttons, which, when activated, cause the Intelli Rig electro-hydraulic component controllers to actuate the hydraulic valves to control the drill.

Semi-Autonomous system: *One Touch* uses Intelli-Rig system hardware to completely automate the drill cycle, although the drill is propelled via manual control. Additionally, at any time the operator of the drill may control the rig manually. ARDVARC One Touch integrates fully with any GPS receivers for mine planning functionality via GPS map technology, indicating where operators should drill holes as well as target drilling depth based on elevation.

Full Auto system:

*Autonomous* is an automated version of the ARDVARC drill control system. It uses the same hardware as One Touch and Intelli-Rig but enables operators to automatically propel the drill from one hole to the next. Autonomous also allows full automation for the drilling cycle, though the operator can manually control the drill at any time.

### ARDVARC technology helps improve drill performance and keeps people safe

- Safety – by physically removing the driller from the drill, particularly when drilling near the toe or the crest, risks are reduced or even eliminated depending on the level of automation
- Utilisation – blasthole



drills commonly only drill 40-60% of the shift time.

Utilisation increases incrementally with the level of technology. The greatest contribution of complete drill automation is increased utilisation of the equipment by enabling mine operators to drill through blast outages, shift changes and operator breaks

- Training and recruitment – if finding skilled drillers or training them is a challenge, automated drill functions can compensate for limited skills. If there is a shortage of operators in general, remote control or autonomy can help resolve the problem. Also, the built-in intelligence in the drill

controls protects against inappropriate operations and helps all drillers perform at a more uniform level

- Reliability and maintenance planning – health monitoring systems provide real-time information on the operating parameters of the drill. This information can be used to detect harmful conditions, preventing damage, schedule on-demand maintenance and reducing maintenance cost, and improve preventative maintenance which leads to improved availability
- Productivity – automated or drilling assist functions increase the average

production rate among all drillers. Combined with increased reliability and utilisation, the overall total productivity can be increased dramatically

- Reporting and management – by displaying drilling information directly in the cab as well as in exported reports, the driller, the operations manager, and the maintenance manager can better address real or potential problems
- Total drilling cost – the effect of increased productivity, better capital use and lower labour costs is to dramatically reduce total drilling cost. One particularly easy saving

to measure is the reduced fuel cost thanks to the compressor management system

- Bench control – a combination of GPS location, auto levelling, and exact hole depth control allows for more level benches
- Fragmentation – combining improved hole straightness and location with integrated strata recognition gives the opportunity to load each hole for optimised blasting and fragmentation. This may shorten the shovel loading cycle, but primarily improves the throughput in the crushing plant or the materials handling systems.

## TPG and Nokia create private network for mines

TPG Telecom has signed a Memorandum of Understanding (MoU) with Nokia in a partnership to develop mobile private network (MPN) innovations for the mining and energy sectors.

The agreement will see the companies collaborate across their extensive portfolios to provide flexible technology solutions and encourage digital and operational technology transformation in mining.

Nokia head of Oceania Anna Perrin said it was important for mining networks to keep up with the technological pace of the industry.

"As our industries adopt transformative technologies like automation and virtualisation, it's essential to have smart, fast, sustainable and resilient private network solutions supporting their operations," Perrin said.

It is expected new innovations will come from the partnership, specifically in productivity and worker safety, as 5G terminals will

connect machinery and sensor assets to an internet of things (IoT) or operations platform to monitor productivity and safety of workers.

TPG Telecom group executive wholesale, enterprise and government Jonathan Rutherford said it was up to companies like his to aid the mining sector into a new age of connectivity.

"This MoU will see us work together to drive new technological innovations to help the mining and energy sectors realise the productivity and connectivity benefits that mobile private networks can provide," Rutherford said.

MPN is an ultra-secure solution for mining companies, allowing interconnectivity between people and things using 4G or 5G technology.

Within the mining sector, MPN enables new applications and supports existing business services using a local network on their premises, providing protected and reliable performance.

5G devices will also enable greater worker communication through improved voice, video and data services, and in the near future, augmented reality to access complex operational resources in the field.

TPG Telecom general manager customer technology solutions, enterprise and government,

Easwaren Siva said there is a strong need for secure, scalable, and reliable networks in the mining and energy sectors, which TPG Telecom was well-positioned to deliver.

"The mining and energy sectors are fundamental to the Australian economy and TPG Telecom wants to help these sectors embrace new technologies, specifically in industrial automation," Siva said.

"This is the network these sectors require, and we will support them on their journey to operate more effectively and safely than ever before."





## Lithium's feast-or-famine future keeps EV makers guessing

Lithium's vital role in electric-vehicle batteries means automakers, miners and investors are racing to figure out how much supply the world will need in the coming years – and also how much it's going to get.

The problem is the predictions vary wildly.

The metal's price has surged fivefold in the past year, reflecting mounting worries about availability. For years, batteries and EVs have become cheaper to make as the technology improved and production stepped up. But now there's a risk that rising costs of raw materials – and lithium in particular – could hobble the transition just as momentum picks up.

The stakes are high for carmakers that are spending billions of dollars betting on a battery-powered future. Mining companies and governments are responding with ambitious plans to boost production. But demand is growing at such a breath-taking pace that it's not clear whether it will be enough.

In a survey of six leading lithium forecasters, estimates for how the market will look in 2025 range from a deficit equal to 13% of demand to a 17% surplus. Projections for the market's size diverge sharply too, with demand forecasts ranging from as little as 502,000 tons to as much as 1.25-million tons.

The gulf between

forecasts reflects lithium's status as a small market on the cusp of seismic expansion, with the average of the six estimates suggesting annual growth of more than 20% for both supply and demand between 2021 and 2025. That compares with typical growth rates of 2%-4% in larger and mature markets like copper, where surpluses and deficits usually equal a fraction of demand.

The forecasts matter because banks use them for everything from gauging future car sales to valuing loans in mining projects. Vague market projections leave more room for sharp price swings when supply panic kicks in.

That could be particularly unnerving for the car sector, which has placed lithium at the center of its electrification plans.

It has spent years experimenting with different chemical compounds to minimize use of other battery metals like cobalt – which is sometimes mined in unethical conditions – while boosting usage of abundant elements like iron. With lithium at the core of virtually every battery technology in commercial use and development, higher prices could quickly start to bite.

For example, if lithium spot prices remain at levels currently seen in China, that could add up to \$1,000 to the cost of a new EV,

according to Benchmark Mineral Intelligence.

Benchmark is among those forecasting supply to fall short of demand, even as it predicts output to roughly double from 2021 levels by 2025. Top lithium miners including Chile's SQM reported annual demand growth of close to 50% last year.

"There's a complete overoptimism about the responsiveness of supply in the lithium market," said Andrew Miller, chief operating officer at Benchmark Mineral Intelligence. "It's very hard to see how it's going to accelerate at the speed that the battery market and electric vehicles are accelerating."

So far, the auto industry has been relatively relaxed about lithium supplies, mainly because they occur in high concentrations in mining-friendly countries including Chile, Australia and Canada.

If anything, worries that large spikes in supply could quickly swamp the market is partly why some of the biggest miners have shunned developing lithium assets. Rio Tinto Group is the only mega-cap miner who's so far been tempted to move into the metal – a market that's still tiny compared with commodities like iron ore and copper.

History shows that even current heavyweight lithium miners like Ganfeng Lithium,

Albemarle, SQM and Livent should be cautious. A spike in prices a few years ago quickly unravelled as producers flooded the market. Some analysts warn it could happen again.

"We have some pretty open-ended supply opportunities opening up," said

Tom Price, an analyst at Liberum who started covering commodities in the early 1990s. "There are really no constraints on resource upgrades and additions for new supply."

On the other hand, there are also good reasons why supply could lag.

The mining industry has a reputation for failing to deliver on targets, and McKinsey & Co. estimates that more than 80% of projects come in late and over budget. Many assets being studied are owned by junior miners who don't have as much experience or existing revenue streams to fall back on as the majors.

### Environmental Hurdles

Even the biggest miners face obstacles to bringing on new supply because of environmental concerns, despite lithium being a key material for a greener world. Serbia last month put a stop to Rio Tinto's plans for a \$2.4-billion mine after a nationwide backlash over the potential environmental risks.

In Chile, home to the world's largest lithium reserves, the mining industry is also running into stiff political headwinds.

But as compelling as the supply risks are, it's the potential for huge demand growth that's really behind the difference in opinions on whether lithium will be over or undersupplied.

While Bank of America Corp. is among the most optimistic on supply, it's forecasting deep deficits once consumption is factored in.

"There's an awful lot of tons that producers need to bring into the market," said Michael Widmer, head of metals research at the bank in London. "We have a disconnect where on the demand side we're pushing very hard, but on the supply side, miners are only just starting to commit."



## Metals, engineering need support to ensure sustainable economic recovery

Seifsa is a national federation representing 18 independent employer associations in the metal and engineering industries, with a combined membership of over 1,200 companies employing over 170,000 employees. The federation was formed in 1943 and its member companies range from giant steelmaking corporations to microenterprises employing fewer than 50 people.

A shrinking domestic market, declining production, weak production sales, a smaller contribution to the economy, increasing joblessness, cheap imports and low investment levels are just some of the issues being faced.

These challenges do not plague metals and engineering only and their knock-on effects are felt throughout the economy owing to its role as supplier and customer into the automotive, motor, mining, construction and other manufacturing sub-industries.

"Manufacturing companies play an integral part in the supply chain of the South African economy and the sector will struggle to recover without support. The sector already relies heavily on demand from government projects to boost its production and sales, especially for products such as steel and other downstream products.

"This is why the government must speed up the implementation of its infrastructure investment plan and reforms across state-owned enterprises as the lack of progress on these and other projects is delaying the revival of our economy," said Seifsa CEO Lucio Trentini.

Some form of protection against the dominance of imports while promoting domestic manufacturing and suppliers can also make a difference, though in the longer term the international

competitiveness of the sector will need to improve before local producers can assume the role of preferred supplier to both domestic and international markets, he stated in the release.

There is also help at hand in the form of the African Continental Free Trade Area agreement, which offers new opportunities for trade on the continent in the metals and engineering sector.

Costs remain an issue for manufacturers. The unexpected acceleration in producer inflation in December highlighted the effect of higher energy prices globally and global supply chain problems.

According to the latest data released by Statistics South Africa (Stats SA), the producer price index for final manufactured goods rose 10.8% year-on-year in December, up from 9.6% in November. Stats SA said coke, petroleum, chemicals, rubber and plastic products were the main contributors to the higher number; these product categories incorporate petrol and diesel prices, which are close to record highs.

Manufacturers also have to contend with falling prices, which benefit buyers of the metals and engineering sector's products, but

put enormous pressure on manufacturers' profit margins, which in turn leads to job losses as companies look for ways to cut costs.

South Africa's official unemployment rate was recorded at 34.9% in the third quarter of 2021 – the highest jobless rate since comparable data began in 2008 – owing to, amongst other things, the deplorable looting that took place in July compounded by the stringent lockdown measures.

The jobless data showed that 660 000 jobs were lost between the third and second quarters of 2021. The broader manufacturing sector lost 13,000 jobs. The disheartening lack of employment opportunities affects the economic status of the country and, more importantly, the livelihoods of all its people.

Industry has expressed its concern about the stubbornly high unemployment rate. Seifsa has called on the government to address the issue, while finding ways to reduce the cost of electricity, diesel and petrol to help put the economy back on track.

The metals and engineering sector is a strategic industry for South Africa, so plans to reindustrialise the sector, including the primary steel

and downstream industries that employ more than 200,000 workers must not be allowed to fail.

The federation has advocated for infrastructure development as a means to promote industrialisation in South Africa, especially in metals and engineering as it feeds into infrastructure projects from an input supplier perspective, but for recovery to take place there is a need for clear purpose and strong support for government projects, Trentini stated in the release.

"While it is not possible to state, with a degree of certainty, how the year ahead is likely to pan out, it is probably safe to say that 2022 will be marginally better than 2021. However, a lot hinges on the government's planned infrastructure rollout and the trajectory the Covid-19 pandemic takes in the country in the months to come.

"We hope that the government will finally deliver on both the Steel Master Plan and the promised and long-awaited infrastructure plan, which is intended to stimulate the economy, and not be distracted by the political agenda when all focus and energy should be firmly directed at economic growth and recovery," he added.





## New dust control products – GRT combats drill and blast dust

Leading dust suppression specialist Global Road Technology (GRT) is unveiling a new range of dust control products as it further establishes itself as an industry leader in reducing the dust pollution caused by Australian mining activity.

Drill and blast activities have long been in the “too hard basket”, however staff working in these operations are some of the most exposed onsite.

In anticipation of the requirements of its mining clients GRT has developed a two-pronged attack on the hazardous, respirable dust generated from drill and blast, with the service offering named the GRT: Drill and Blast Dust Control process.

Phase one includes GRT 12X, a product that targets the dust generated by drilling for blasting and exploration. It super-activates drill water so it saturates and captures the fine, hazardous dust drilling can generate, preventing it from becoming an airborne hazard.

The second product that forms part of this offering is the GRT: DC Binder, a polymeric additive that prevents hazardous airborne dust from being generated from the piles of fine Drill Cuttings (DC) by creating a tough surface crust that binds the hazardous dust particles in place.

For GRT general manager Daniel Grundy, the development of these products is a response to the current use of water by the mining industry as a major plank of their dust control reduction schemes – an approach that is largely ineffective in stopping the spread of dust particles.

“Trying to suppress silica and coal dust using water alone as a tool is quite frankly ineffective and can even be a wasteful use of this valuable resource,” Grundy said.

“This is a rather blunt assessment, but the fact is that traditional water-based methods employed by mines and quarries to mitigate the generation of coal, silica, and other hazardous dust are ineffective due to water’s chemistry and wasteful due to the amount of continual watering required to try and manage mining dust.

“GRT 12X and its sister product GRT: DC Binder have been developed and trialled over a half decade period as a scientific response to this issue and present an effective, sustainable, safe, non-toxic, biodegradable alternative that stops dust from drill and blast activities at the source protecting workers and even neighbouring communities.”

This technology is designed by GRT to resolve the issues caused by traditional methods of dust suppression in that traditional methods using solely water to capture particulates are quite ineffective due to the respective properties of the two particles – resulting in them repelling each other like two positive ends of a magnet.

GRT is releasing products at a time when the legislative environment across the country is combining with community pressure, placing airborne dust pollution and dust-related lung disease firmly on the agenda of major mining companies as pressure grows for them to showcase how they are proactively reducing its onsite spread.

This follows a three-year period in which each of Australia’s state governments have implemented tighter legislation around dust pollution.

This legislative tightening is occurring at the same time the Federal Government has established a National Dust Disease Taskforce (the Taskforce) to develop a national



approach for the prevention, early identification, control, and management of occupational dust diseases in Australia – partially due to growing community concerns around airborne lung-diseases.

In the face of the changing political and business landscape, GRT developed GRT: DC Binder and the GRT 12X Dust Suppression as an industry-first approach in that the products allow miners to take a whole-of-site approach when aiming to reduce the spread of particulate dust by stopping its spread at the source.

This prevents the super fine dust from becoming airborne when disturbed by the wind, vehicles, or even members of the blast crew as they work in the drill pattern area.

Grundy said the significant amount of time, effort and dollars invested in these products is worthwhile, as it epitomises GRT’s philosophy of dynamic dust management – an approach that separates it from other

operators.

“This product set is representative of our entire philosophy at GRT where we focus our efforts into dynamic dust management – that is proactively resolving the problem of air pollution at its source via our engineering processes and product suite to stop the issue in its tracks,” Grundy said.

“The ultimate aim for us is to end dust as a mine site hazard – with these products designed to provide comprehensive, whole of mine site solutions to ensure that workers, communities, nearby farmers, and the environment aren’t negatively impacted by mining activity.

“To achieve this goal we have become one of the few companies in our field that focus on solutions that account for the entirety of the mine-to-port process – meaning that at every step of the journey a GRT product is designed to provide protection for workers and communities alike from dust pollution.”



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## Giant miners to see record profits slip as cost pressures bite

Investors in the world's biggest mining companies will this month be watching for signs that mounting cost pressures and the impacts of slowing Chinese growth could further erode record earnings.

Miners are likely to report a drop in profits. The top-five western diversified mining companies, including iron-ore giants Rio Tinto Group, Vale and BHP Group, may see combined 2021 second-half earnings of \$73-billion, according to analysts' estimates, compared to \$82-billion in the first half.

Although elevated prices for metals mean profits remain robust on a historical basis, the dip is reflective of the headwinds that developed over the period.

"That's going to be a theme: With the bumper profits that they're enjoying, they are rewarding shareholders with dividends rather than ploughing it back into expansion," said David Bassanese, chief economist at fund manager BetaShares in Sydney. "That shows that there's not a lot of confidence" for the longer-term, with uncertainty about China at the forefront of concerns, he said.

Threats to economic growth in the world's largest metals consumer are clouding the outlook for miners and especially iron-ore companies.



China's property market, which consumes around a third of the country's steel output, has been cooling, Bloomberg Intelligence expects new home starts to decline by 5% this year. And Beijing's bid to cling to its Covid-zero status, even as regional outbreaks become more frequent, is the X factor that's likely giving some resource executives sleepless nights.

The pandemic has been a double-edged sword for the mining sector over the six months to December 31. On the positive side of the ledger, the trillions of dollars in stimulus packages ignited demand for commodities

like iron ore, copper and aluminium, driving prices sharply higher and sending inflation pressures rippling through the global economy.

On the negative: rising operating costs are set to be a feature of the latest set of reports. Labour shortages are becoming an increasing challenge to ore producers in the Pilbara region of Western Australia, a state which remains subject to strict borders controls to keep the Covid-19 out. Supply chain bottlenecks have also seen global shipping rates ratchet higher.

BHP and Rio have said that a lack of workers in key roles are having an

impact on their operations. Fortescue Metals Group, the world's No. 4 ore producer, reported last month that its costs had risen 20% over the past 12 months driven primarily by rising fuel prices and labour shortages.

Vale is expected to have offset volatile ore prices by selling down its stockpiles and getting some cost relief last quarter. Still, the market will be wary of the potential for increased provisions for remedial action following the Samarco dam disaster.

The Brazilian company is still trying to get its base metals division back on track after a strike and an incident with workers trapped in a mine in Canada. That affected nickel and copper production in the third quarter.

All up, iron-ore miners had a bumpy ride in the second half of 2021. Prices collapsed from peaks north of \$230 per ton in May to the mid-\$80s in November after China tightened curbs on steel production to meet stricter environmental standards. They have since rallied afresh on expectations for a rebound in steel output after Beijing relaxed climate targets, yet price volatility remains a risk for the earnings outlook.



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