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Chile aims to outline state lithium firm model this year

Chile's government, which has pledged to establish a state lithium firm to develop the ultra-light battery metal, hopes to establish a model for the company by the end of the year, mining minister Marcela Hernando told local paper La Tercera.

The South American country is the world's second largest producer of lithium, a key component for electric car batteries, with its domestic industry currently dominated by two private firms Albemarle and SQM.

However, the government of new leftist President Gabriel Boric, like administrations in Mexico and Argentina, is keen to get more closely involved in the booming market for lithium, which has seen prices soar over the last year.

Hernando said a specialised group was being formed to define the best design to operate the company.

"We hope to have the proposal for how this company will be as an institution and the business model in which it will operate before the end of the year," she said.

The minister reiterated that the government was open to the participation of private capital in the firm, although with the State as the main shareholder.

President Boric, who came into office in March, said during the election campaign that Chile should not commit the "historic mistake" of privatising its resources again and reiterated his interest in creating the company for the development of lithium.

Hernando added that lithium would not be included in the plans to apply a mining royalty, as part of an ambitious tax agenda promoted by the government.

"The evaluations we have made is that it is very complex, since lithium is an industry that is not very mature," she said.

MRI, Quantum in flake graphite deal

Quantum Graphite has executed a binding offtake agreement with Swiss-based global metal and minerals trader MRI Trading for the sale of 100% of all of the flake graphite produced at its Uley 2, Stage 1 project in South Australia, for a period of five years.

A leading global metals and mining trading group based in Zug, Switzerland, MRI is uniquely positioned to add flake graphite seamlessly to its existing minerals coverage and provide the Quantum with ready access to MRI's customer base across Europe and Japan.

The head of MRI's Japanese commercial team, Andrew Briscoe, said the synergies with Quantum were "compelling".

"Our due diligence showed us the obvious overlap in both the key markets and key customers. The icing on the cake is our logistics fit in Australia and the Asia-Pacific region generally. Our diversified freight capabilities offer options beyond the company's reach and deliver a clear competitive advantage."

Quantum worked closely with MRI's head office in Zug on the strategic fit of the organisations.

Senior member of MRI's management, Tristan Zaniewicki, said the company recognised that through this deal, it would become the largest trader of natural flake outside of China.

"Once we satisfied ourselves of Quantum's technicals and its diverse product coverage, our focus was culture. As the exclusive Uley 2 offtake partner, the parties will work closely together and with prospective customers. Our cultural fit was critical and we were pleased to work with a board that have the same mindset," he said.

Quantum managing director Sal Catalano said the parties were acutely aware in negotiations that the agreement had to extend well beyond a simple minerals supply arrangement.

"Emerging thermal storage technologies, the explosive demand forecast for Li-ion battery production and the changes to the existing supply chain paradigm, required an agreement structure that would cope with rapid change in the marketplace," he said.

The parties have agreed that the market price methodology will include a two-step process that utilises data from these established data providers.

The first step is the determination of the prevailing market price for the relevant flake specification. This agreed market price is obtained directly from the schedule of prices published by market data providers strictly limited to those specified in the offtake agreement.

Where a price is not available for a particular specification of Uley 2 flake, the market price adopted will be that applicable to the flake specification closest to the relevant Uley 2 flake product.

The second step of the pricing methodology is the determination of the final selling price by the application of an agreed premium or discount to the agreed market price.

Cat rope shovel enhancements boost reliability

Today's Cat 7495 and 7495 HF Electric Rope Shovel (ERS) models feature multiple design enhancements to the lower structures that increase machine reliability and significantly lower overall total cost of ownership.

These upgrades cover the track (crawler) frames, swing rack and rollers, propel gearboxes, and rotating undercarriage.

Combined, the design advancements can improve total cost of ownership up to 6% per operating hour and improve physical availability of the ERS up to 0.63%.

All updates are found on current-year models and can be retrofitted independently in the field to allow existing customers to realise these substantial gains.

Track roller frame

A reengineered bolt-on design for track link sliders eliminates the need for casting welds. Cat rope shovel customers can benefit from up to a 22% cost-per-hour reduction with extended wear life and no maintenance.

Integral wear indicators provide visual reference to help service technicians plan for slider maintenance.

Track frame life is enhanced with increased frame thickness, lowering stress in the plate for improved reliability.

A new super bolt arrangement features shorter middle bolts, improving joint stiffness and maintaining preload. Access for cleanout has been improved with a three-hole track frame bell housing.

Distributing shovel weight more evenly to the crawler side frame, the updated tapered shear ledge reduces end loading as the ERS pitches forward during digging.

New lower side frame stiffeners maintain increased track clearance to the tracks, while improving rock protection.

Saving approximately 100 hours of field assembly time, the bolt-on motor base eliminates field welding and improves motor bolt access.

Set screws simplify locating the base on the crawler and simplify motor alignment.

Swing rack

The swing rack absorbs the stress from every load. The 7495 and 7495 HF models now have a single-piece swing rack casting that eliminates previous vertical welds to improve ERS durability.

The number of core holes have been reduced from 20 to four, positioned strategically in low-stress areas of the swing frame and located outboard to increase web strength. Improvements to the weld joint between the swing rack and car body further reduce stress.

An updated single-piece roller path increases roller life and eliminates seams to improve ride and prevent rollers from coming loose. Five symmetrical roller segments are now preassembled, improving alignment quality and installation efficiency.

The upgraded thrust rail design improves access for inspection and retightening, while adding support to the thrust rail during operation.

Outboard propel

The redesigned propel system eliminates the need to remove the propel transmission when servicing the drive tumbler and propel shaft, since they are now replaced from the outboard side of the machine.

This significantly improves serviceability of the drive, decreases maintenance downtime by as much as 75% and lowers operating costs by as much as 10% versus the previous design. The component's design updates extend rebuild life to up to 30,000 hours.

Sealed and continuously lubricated tapered roller bearings more evenly distribute thrust to improve propel durability. Fresh grease flows equally through both sets of bearings, eliminating potential contamination from bearing surfaces.

Propel gear case metallurgy has been optimised to improve toughness, while improved microgeometry enhances gear mesh to reduce contact wear.

Rotating undercarriage enhancements

Compatible with all ERS machines equipped with 79-in (2 006-mm) track pads, a new track pad design improves structural support and steel chemistry.

A proprietary heat treatment process increases hardness by 15% and toughness by 30% to improve roller path and drive lug wear.

The track pin design features improved alloy composition and higher toughness. A new track pin removal pocket for 7495 HF models offers an easy-to-use pin removal solution that features a weld-free integrated vertical surface to keep the cylinder stabilised during pin removal.

Unloved since Fukushima, uranium is hot again for miners

Uranium miners are racing to revive projects mothballed after the Fukushima disaster more than a decade ago, spurred by renewed demand for nuclear energy and a leap in yellowcake prices after Russia's invasion of Ukraine.

Spot prices for uranium have doubled from lows of $28 per pound last year to $64 in April, sparking the rush on projects set aside after a 2011 earthquake and tsunami crippled Japan's Fukushima nuclear power plant.

"Things are moving very quickly in our industry, and we're seeing countries and companies turn to nuclear with an appetite that I'm not sure I've ever seen in my four decades in this business," Tim Gitzel, CEO of Canada's Cameco, which mothballed four of its mines after Fukushima, said recently earnings call.

Uranium prices began to rise in mid-2021 as several countries seeking to limit climate change said they aimed to move back to nuclear power as a source of carbon-free energy.

A quest for secure energy supplies has added to the potential demand.

Unrest in January in Kazakhstan, which produces 45% of primary global uranium output, had already driven prices further when Moscow's Feb. 24 invasion of Ukraine spurred a 50% rally.

Russia accounts for 35% of global supply of enriched uranium.

Prices have retreated since a peak in April, but John Ciampaglia, CEO of Sprott Asset Management, which runs the Sprott Physical Uranium Trust, told Reuters Moscow's invasion had "shifted the energy markets dramatically".

"Now the theme is about energy security, energy independence and trying to move away from Russian origin energy supply chains," he said.

There are about 440 nuclear power plants around the world that require approximately 180 million pounds of uranium every year, according to the World Nuclear Association.

Uranium mines produce about 130 million pounds, a deficit that mining executives predict will widen even if idled capacity by major producers such as Cameco and Kazakhstan's Kazatomprom comes back online.

The supply gap used to be filled by stockpiled material, much of which came from Russia.

Now, miners are dusting off feasibility studies for mothballed mines and reviving projects.

In Australia, uranium producers – including Paladin Energy, which aims to restart its Langer Heinrich uranium mine in Namibia, idled over a decade ago – have raised close to A$400 million ($282.08 million) in share sales over the last six months to fund exploration and resuscitate mines on three continents.

"With all of the additional demand that's coming from the new nuclear (plants), the thesis is that over a five or 10-year period, that additional demand will just dwarf those volumes coming back to market," said Regal Funds Management analyst James Hood.

China plans to build 150 new reactors between 2020 and 2035 and Japan also aims to boost nuclear capacity as does South Korea.

In Europe, Britain has committed to build one new nuclear plant every year while France plans to build 14 new reactors and the European Union has proposed counting nuclear plants as a green investment.

Easier said than done?

Delivering the new reactors, however, will be a challenge as repeated delays and cost-overruns could be exacerbated by the supply chain problems following the pandemic and the additional disruption of the Ukraine war, making demand for uranium hard to predict.

Many environmental campaigners, especially in the West, also remain opposed to nuclear energy because of the waste it generates even though atomic power is emissions-free.

Advocates of nuclear energy say small modular reactors are a solution to the difficulty of bringing on new capacity.

Keith Bowes, managing director of Lotus Resources, which owns the idled Kayelekera uranium mine in Malawi, says modular reactors will be a major source of growth from 2028 onwards.

Others say the traditional obstacle of high cost is less of a problem given the sharpened focus on security of supply.

"No longer is price the determinant, it's now security of supply," Duncan Craib, managing director at Boss Resources told the Macquarie Australia conference on May 9.

Boss will make a final investment decision soon on developing the Honeymoon uranium mine in South Australia, aiming for first production 18 months after any go-ahead.

Sprott's Ciampaglia said uranium could hit $100 per pound in the long run. Prices peaked around $140 per pound in 2007.

This year's rally has taken them to levels last seen in 2011 in part as a result of Sprott's activity in the market with its uranium funds growing from near zero last year to about $4 billion now.

Ciampaglia said Sprott's buying is in response to investor demand: "The Trust provides investors with a vehicle to express their view on physical uranium."

Smaller uranium developers also want to get involved, but will need prices of at least $60 a pound to ensure the economic viability of projects, industry watchers said.

Even then there would be risks. The restart of idled capacity from uranium giants could disproportionately hit smaller players while community opposition in some areas remains.

"No mine development or restart of an idled mine is easy or without challenges," said Guy Keller, manager of Tribeca Investment Partners' Nuclear Energy Opportunities Fund.

Joy Compak Next Gen hydraulic control system helps improve performance of high production longwall systems

High-performance valve technology helps improve cycle times by up to 12%*

When mining in challenging, unpredictable conditions, operators need confidence in their longwall systems, and building that confidence starts with the hydraulic functions in powered roof supports (PRS). Improve the performance of your high production longwall systems by equipping your PRS with the multifunctional Joy Compak Next Gen hydraulic control system, and help facilitate your shearer cutting rate with exceptional cycle time performance.

Engineered to be durable and reliable in rugged environments, the Joy Compak system features corrosion-resistant materials on valve block assemblies, components and the main body. With a reduced number of components to lessen wear and tear, the spool valve in the system is engineered to handle higher flow rates, to help reduce the risk of part failure and promote extended life. Providing flexibility to suit the individual needs of your operation, the Joy Compak Next Gen hydraulic system can be conveniently upgraded or retrofit to any PRS system (regardless of manufacturer).

Increase productivity

The high-performance valve technology of the Compak hydraulic control system helps improve cycle times by up to 12%, compared to the previous model. Designed with operators in mind, this hydraulic system's overall size is reduced by up to 27%** and weight by up to 30%**, making it easier to position, while improving accessibility. Hosing position has also been conveniently located for better access.

The reliable hydraulic valve system helps control modern automated longwall powered roof supports from the Faceboss electronic control system using solenoid control or through manual control with the solenoid push button override function. Ergonomically positioned for ease of access, operators can control the main override function easily and effectively through an integrated pushbutton within the solenoid.

High reliability

Seals play a crucial role in the functionality of the hydraulic spools that operate your roof supports' functions, and Komatsu's innovative and proven seal technology helps prevent leakage in your hydraulic spools. A simplified, standardised hydraulic circuit design helps provide a reduction in the number of spool valves without impacting performance of the Compak hydraulic system. This design minimises fitting and connecting hoses, to help reduce potential leak points.

Easily expand the system (over 16 functions) to increase functional requirements to suit your operation's needs. For example, a standard 10-spool valve can be expanded with ease through separate two- and four-spool expansion modules.

Modular approach streamlines maintenance

To help reduce lead times for replacement parts and streamline maintenance, the hydraulic control system features a modular design incorporating a series of standard components. Easy to change cartridge-style construction makes replacement straightforward and manageable. Manifolds, valve assemblies, cartridge valves and fittings are all standard as part of the system's modular design. The modular approach also makes upgrades easy.

**Comparison based on previous model*
***Comparison based on previous model (like-for-like designs) without extra add-ons*

GR Engineering to build Bellevue processing plant

GR Engineering Services has been awarded a preliminary works agreement for the engineering, procurement and construction (EPC) of the one million tonnes per annum gold processing plant and associated infrastructure for the Bellevue Gold Project in Western Australia.

GR Engineering will immediately commence design engineering services and ordering of long lead and design critical path equipment, including the ball mill, crushing equipment, screens agitators, leach and tailings thickeners, prior to entering into an EPC contract.

Bellevue Gold.

Bellevue managing director Steve Parsons said GR Engineering knew the project well from its work during the study phase.

"GR Engineering is one of the most recognised and reputable name in the Australian gold processing industry," he said.

"It's fantastic to have another Tier 1 business involved in the development and construction phase.

''Commencing manufacturing of these long-lead critical components of our processing plant de-risks the construction schedule and puts Bellevue on the pathway to first gold in the second half of 2023.

"The appetite among leading contractors and suppliers to be involved with our project speaks volumes about its strong future".

GR Engineering managing director Geoff Jones said the project further enhanced GR Engineering's reputation as the leading gold EPC contractor in Australia.

"GR Engineering continues to build its pipeline of work in FY23 and future years," he said.

Latest crushing and screening developments on show at Hillhead

Aggregates producers are looking closely at their operations these days following the recent pandemic issues. With production predicted to increase as the industry returns to normality it will be critically important to have quarry and mining operations hitting on all cylinders. There is no doubting that the welcome return of the Hillhead exhibition in the UK and Bauma in Germany will give equipment manufactures old and new the opportunity to showcase their latest offerings to a large international audience.

Crushing and screening plant will once again be at the forefront of attention with live demonstrations taking place at Hillhead.

Fondly referred to as 'Crusher Alley', this area draws visitors across the whole western end of the Hillhead showground to see a range of tracked and skid-mounted crushers and screens, scalping grids, and stockpiling conveyors.

So which companies are set to launch their latest offerings and what's new?

MQW takes a peak look at some of the developments on show according to companies press releases.

KLEEMANN'S NEW EVO2 GENERATION FOR SUSTAINABLE USE

Environmentally sound combined with an economic solution

The jaw crusher MOBICAT MC 110(i) EVO2 and the cone crusher MOBICONE MCO 90(i) EVO2, with their efficient crusher direct drive, have a holistic drive concept that forms the basis for high cost-effectiveness.

Crusher direct drive with electric auxiliary drives – fuel-efficient and quiet

Both machines of the new EVO2 generation are equipped with a patented power train. The crusher is driven directly, enabling high fuel-efficiency, via a reliable fluid coupling. Conveying components, such as the vibrating feeder, the double-deck prescreen or the discharge conveyors, are all-electric. A robust and easily accessible gearbox guarantees efficient power transmission. It not only operates with a high level of efficiency but also has ideal protection against dust. Downtimes can be avoided to a large extent. The power and load-dependent fan drive also ensures low-noise and economical operation. Operation in ECO mode can additionally reduce fuel consumption as well as wear in idle phases. The plants can be optionally equipped with a heat package (-15 to + 50 °C) or cold package (-25 to +40 °C). The cold package has an autonomous auxiliary heater with a convenient timer function.

Environmentally sound operation – less noise and dust

In the new drive concept, the speed of the cooler fan and therefore also the cooling capacity is controlled automatically, which considerably reduces the noise level. Apart from less dust penetration thanks to a lower volume of moved cooler air, work near to the machine is a lot more agreeable for the operator.

For the jaw crusher MOBICAT MC 110(i) EVO2, which is frequently used in urban environments, an optional noise protection package is also available. The considerably reduced noise level would even permit work without special ear protection – depending on the material to be processed, further environmental conditions and local regulations.

To reduce dust, the machines are equipped in the standard series, among other things, at the crusher inlet and crusher discharge conveyor with water nozzles and the corresponding technical infrastructure. As a result, an optionally available water pump or an external water source, if available, can be used. Optional belt covers also contribute to an improvement of the air quality during crushing.

These measures benefit the machine operator, the further peripheral devices on the job site, local residents and the environment.

MCCLOSKEY INTRODUCE THE C2C COMPACT CONE

McCloskey International will use the exhibition to unveil the latest addition to the company's cone crusher line-up – the C2C. Featuring the powerful MC200 cone, the C2C brings all the power of a 200hp cone crusher to a compact footprint that offers high manoeuvrability together with a host of features aimed at boosting productivity in aggregate, construction, demolition, and recycling applications.

According to McCloskey, the machine is designed for superior performance with high capacity, better product quality, optimum versatility, and improved fuel efficiency. Standard features include premium-quality components, unrivalled ground-level access, full-size MC200 cone, powerful engine, efficient conveyor design, and continuous load and material monitoring.

The C2C delivers high production from material feed to end-product stockpile owing to its innovative material flow features. A low feed height, large 6.2 cubic metre (8.1 cubic yard) capacity Hardox-lined hopper allows for stop function, while the unrestricted feed opening improves intake capability and reduces the risk of blockage.

As the material enters the cone chamber, features including a long stroke and variable speed contribute to high productivity, whilst ensuring the highest quality of end product. Moreover, multi-layer crushing delivers greater capacity and better reduction and shape with less liner wear.

As the material moves to the heavy-duty 48in wide conveyor, the large gap between the crusher discharge and main conveyor feeder enhances material flow. Stockpiles can be formed up to 3.3m (10ft 10in) in height, and with ground-level access the belt is easy to service and maintain.

Power is built into the C2C, with a robust, 280kW (375hp) on-board engine along with high-capacity fuel and hydraulic tanks to reduce the number of refuelling intervals. Mobility on site and between sites is facilitated by remote-controlled tracks that easily move and position the crusher. The C2C can be setup and ready to work in less than five minutes.

Technology has been a key factor in the development of the C2C, with a 12in DSE control panel for maximum operational performance and reliability providing push-button control of the cone, track, and feeder functions. The crusher is fitted with a telematics modem for the new 365SiteConnex program – a complete connectivity solution for highly accurate monitoring of McCloskey products.

As with all McCloskey equipment, safety is paramount, and the C2C is equipped with a number of features to ensure the workplace and the operator are secure. Engine safety shutdown systems, start-up alarms, full safety guarding, external maintenance access, and a tagout capability on the isolator all contribute to the safe operation and maintenance of the equipment. Ground-level access also promotes safety and allows for quick service and maintenance, thereby reducing downtime.

'The C2C is another example of McCloskey designing and delivering on what our customers are asking for,' said Toni Laaksonen, senior vice-president of McCloskey International. 'We listened to producers who needed the power of a full-size cone, but also the ability to move their equipment easily on and around their sites. There has been no compromise in power or productivity with the C2C; it's a perfect example of leveraging the best features from our existing cone crushers and adding mobility based on how our customers use the equipment every day.

POWERSCREEN- IN TOUCH WITH TOMORROW

Company to showcase new machines, innovative digital solutions, and alternative power offerings

Situated on their usual stand in its familiar location, global crushing and screening experts Powerscreen are looking forward to welcoming dealers and customers alike after the lengthy four-year wait.

Commenting on the upcoming exhibition, Powerscreen business line director and general manager Sean Loughran said: 'To say that we are excited to be back doing what we do best at Hillhead would be an understatement. It has certainly been a challenging few years – but the team at the factory has been working extremely hard behind the scenes and we are looking forward to sharing the results of this work with attendees.

As well as the famous hospitality that attendees have become accustomed to on the Powerscreen stand, the company says there will be a display of machines and technologies that are very much 'in touch with tomorrow'. The static machine line-up will include: the latest addition to the highly successful Chieftain range – the game-changing Chieftain 1700X triple deck screener; the high-production HLF75 orbital conveyor; and the flagship of the new Titan range of machines, the Titan 2300, which has been turning heads since its debut at the end of 2021.

On the technology side, there will be a showcase of innovative digital solutions and an insight into the alternative power offerings which will play an important role in preserving the planet.

Conveniently located directly in front of the Powerscreen stand is the rock-processing demonstration area – where the company will showcase three working machines: the new Premiertrak 450, the bigger and better Trakpactor 480SR, and the new Chieftain 2100XE with its hybrid-electric drive system.

Powerscreen product and applications manager Neil Robinson commented: 'Pretty much everything on display at Hillhead 2022 is the result of a collaborative effort between our team members, dealers, and customers, and it's great to be interacting face-to-face again. We look forward to seeing some familiar faces and some new ones on the Powerscreen stand during the show.'

HYBRID SAVES UP TO 25% ON FUEL COSTS

Electrification and digitalisation proving to be a win-win combination for RM customers

Sharply rising fuel prices, legal requirements for emissions, expanding your business, and environmental protection – there are many reasons for switching to hybrid machines. As a pioneer in electrification, RM Group have been engineering crushers with electric drives for 30 years. This expertise is integrated into RM hybrid crushers and screens. Two of these crushers and an RM MSC8500e mobile hybrid screen will be on display at Hillhead 2022.

Saving a quarter of fuel costs sounds extremely interesting, and not just in times of rocketing fuel prices. This is how it works: On RM hybrid crushers, an electric motor drives the crusher rotor. The electric drive compensates for peaks in power demand during operation, allowing the diesel engine to run at a constant speed without fluctuations. The result is a much lower fuel consumption – up to 25% lower, as proven by field data from RM crushers recorded by the new RM XSMART fleet-management and condition monitoring tool.

Even if the RM hybrid machine is running on diesel 100% of the time, it saves up to 60% in annual operating costs compared with a hydraulic machine, because in addition to lower fuel consumption, costs for hydraulic oil and servicing are also reduced.

'Low running costs have a massive impact on the total cost of ownership of the machine. That's why, despite the higher initial cost of hybrid systems, they often pay for themselves in just a few years,' agreed Paul Donnelly, managing director of Red Knight 6, and Ian Burton, sales director of Taylor & Braithwaite.

Both of the RM Group's UK sales partners will be demonstrating and explaining the RM 100GO! hybrid to visitors at this year's Hillhead show. If a hybrid crusher is combined with a hybrid screen, it is even possible to achieve fuel savings of up to 30%. A combination will be on display on RM Group's stand: an RM 120X crusher and an RM MSC8500e hybrid screen. The savings calculator on the RM website provides a detailed comparison of your potential savings.

With a hybrid crusher or hybrid screen, it is also possible to operate purely electrically and emission-free. This opens up completely new application possibilities for tunnel construction sites, inside buildings, and in city centres. RM crushers easily comply with the strictest legal requirements in terms of exhaust, dust, and noise emissions.

For example, an RM customer in Latvia recently purchased an RM 100GO! hybrid – the same as the one on display at Hillhead – to crush dolomite electrically and to be able to meet the high legal requirements for road construction. Thanks to the intelligent networking of the RM NEXT

Generation machines, a crusher such as the RM 120X hybrid can also power the RM MSC8500e, or both can be plugged into the mains power supply.

Whether it is fuel consumption, maintenance intervals, throughput, operating hours, or pinpointing the location of RM equipment, RM XSMART is the digital assistant that keeps all this information available at any time via smartphone, tablet or computer. This RM Group fleet-management and condition monitoring tool uses real-time machine data to simplify the everyday work of machine operators, workshop managers, rental fleet managers, deployment co-ordinators, and owners.

'We don't want our customers to waste time doing paperwork for their machines. We want our customers to make the highest profit, and we want to provide them with the best service. That's also why we are focusing on digitalisation,' said RM chief executive officer Gerald Hanisch.

'With just a few clicks, the data can be broken down to a defined time period. Because the operating hours are recorded automatically, it is no longer necessary to manually log hours at regular intervals for invoicing or as proof for the authorities.'

ANACONDA EQUIPMENT EXCITED TO BE BACK

New Anaconda J12 mid-sized mobile jaw crusher to be shown for the first time in Europe

Anaconda Equipment are excited to be returning to Hillhead, where they will be located alongside their parent company, the McLanahan Corporation. For more than a decade, Anaconda Equipment have proven themselves as a reliable partner in the mobile screening and conveying industries, and since 2020 the company has been supplying a full product line of crushing, screening, conveying, and washing equipment.

During the show, Anaconda plan to introduce their new mobile crushing line by exhibiting the J12 jaw crusher for the first time in Europe. The Anaconda J12 is a mid-sized machine designed to offer operators and contractors excellent reduction of the initial feed material, continuous production, and a consistent product shape.

Designed primarily for quarrying and mining applications, the versatile crusher features a 1,100mm x 700mm (28in x 44in) Universal Crushers jaw chamber. Anaconda say their crushers are designed to be as user-friendly and efficient as possible with a direct hydraulic drive system that allows for the jaw to be reversed, plus Cummins L9 performance engines that offer low fuel consumption and eliminate the need for exhaust gas recirculation (EGR).

Also on display will be the Anaconda DF514 scalping screen. Already proven in European markets, the DF514 mid-sized scalping screen is available in multiple variants that allow it to adapt to different applications. For example, the ability to select either an apron feeder or belt feeder allows customers to make changes to the scalper before the feed material is passed to the twin-deck (5ft x 14ft) screenbox.

Both the J12 jaw crusher and DF524 scalping screen can operate as stand-alone machines or work in combination to improve productivity for the end-user's application.

The Anaconda J12 mobile jaw crusher

Meanwhile, McLanahan will be exhibiting their UltraWASH 6206 and UltraCRUSH modular systems, demonstrating the diversity of the McLanahan family of companies with mobile tracked and wheeled units as well as static modular crushing and washing solutions.

ASTEC TO SHOWCASE OVER A CENTURY OF EXPERIENCE

Built for maximum mobility, Astec say their mobile jaw crushing plants, such as this GT125, feature Pioneer-series jaw crushers, offer up to 25% more capacity than competitive models, and are equally effective in aggregate or recycling applications

Industry veterans Astec Industries are bolstering their established international presence by showcasing their mobile crushing and screening range at Hillhead.. Having recently consolidated the company's legacy brands under the Astec banner (including stalwarts such as Kolberg-Pioneer, Osborn Engineering, Telsmith, Johnson Crushers International, and Astec Mobile Screens), Astec will use the renowned quarrying exhibition to connect with customers and partners alike – both new and old.

With one of the most comprehensive product offerings in the marketplace, ranging across crushing and screening (mobile, portable, and static), material handling, washing and classifying, rock breaker technology, and the asphalt and concrete sectors, Astec are excited about growing their market presence globally.

The company has taken its 16 industry-celebrated brands, such as KPI-JCI, Astec Mobile Screens, Osborn, BTI and Telsmith in the crushing, screening, and aggregate processing markets, and Carlson, Roadtec, Rexcon, Con-E-Co and BMH in the concrete and asphalt sectors, and recently assimilated the product range under the Astec brand name.

This restructured framework guided the company to simplify its business, focus on its customers, and grow as a connected partner in the industry whilst leveraging the strength of a century of proven design. With the brands consolidated under the one name, Astec's focus is to be a partner the industries that build the infrastructure that physically connects the world. It is this commitment that has driven their decision to unify as one company under the 'Built to Connect' framework.

Ron Earl, group vice-president of sales and marketing for Astec, commented: 'We are excited to embark on the next phase of our development journey. Astec have a great story to tell and our decades of experience in the industry make us a credible alternative to many of our competitors.

'Astec Industries are soon to celebrate their 50th anniversary, but some of that success needs to be attributed to companies that exceed that mark. Our no-nonsense products are well established within the industry and built to withstand the demands of the sectors in which we operate.

'Keeping our customer at the centre of our business remains a core focus. We are one of the few OEMs that has an established global footprint to support sales, installation, service, and parts from our strategically positioned bases. We have manufacturing bases and regional offices in North America, Latin America, Canada, Africa, and Ireland, with additional regional offices in the Middle East, Asia, China, and Australia to help serve customers locally.

'We are currently recruiting additional dealers to help represent us. Hillhead will provide a great opportunity for everyone to meet the team, hear about our investment, and discuss the strategic expansion of one of the most notable names in the industry.'

Astec have invested time and money into their European facility to help support their customers and distribution network globally in all aspects of sales, service, support, and spare parts. The streamlining of the company's internal structure and operations has been a huge factor in improving efficiency and driving growth. Additionally, further investment into a dedicated ESG focus, not only in terms of developing their zero-emission technologies, but also ensuring that Astec fulfil their obligation as a good corporate citizen and implement relevant sustainability initiatives as well as sound corporate governance.

Stephen Whyte, group vice-president of product management with Astec, elaborated: 'Hillhead brings a welcome opportunity for all of us to get back out and see equipment in operation at an exhibition, and I encourage you to come view the solutions we have to offer. We are fortunate to have such a strong product portfolio and, as a company, we are invested in leveraging our product and application experience to continue developing innovative and sustainable technology.

'Connected equipment will help reduce operating costs and, ultimately, make the lives of our dealers and customers easier. Local parts availability and product support are vital alongside a product focus on performance, telematics, industrial styling, and the drive towards zero emissions, as we work to grow our global market share. We are looking forward to displaying some of these innovations to everyone at Hillhead and helping them discover the full breadth of our product range.

Astec, who are currently seeking additional partners that share their reputation for quality, customer focus, and innovation, would welcome any expressions of representation interest in advance of the show, by emailing: hillhead2022@astecindustries.com

CIRCULAR-MOTION VIBRATING SCREEN WITH MANY INNOVATIVE FEATURES

thyssenkrupp screens of the CK line have already been used successfully worldwide for many years. With screening areas up to 17 m², in models with two or three screening decks, they are ideally tailored for screening aggregates, gravel, ore, and coal. The new series offers operators a significant plus in terms of reduced manufacturing costs, installation effort and maintenance, so that the designation CK+ was chosen for it.

The focus of this development was on the drive concept, and the know-how for this was already available with the revolutionary drive system of the goovi® multi vibrating screen. This concept has now been transferred in a simplified form to the CK line of circular-motion vibrating screens. For this reason, compact, lifetime-lubricated standard unbalance motors are used, which are flanged symmetrically and directly to the sidewalls; these are synchronised by means of a connecting rod.

Customer benefits

- The number of rotating and moving parts has been drastically cut, as a result of which maintenance requirement, failure probability and accordingly downtime are automatically reduced.
- Belt guards and motor platforms in the steel structure are not necessary at all with this concept. Accordingly, a lighter and less complex steel structure can be designed and the installation time is shortened significantly.
- The screen support with rubber spring elements and an adjustment option for the inclination of the screen ensures quiet and safe operation and enables, thanks to adjustment of the screen inclination, optimisation of the product quality.
- As the connection dimensions are identical, CK screens of the previous generation can be easily replaced with CK+ screens with direct drive. This means that screen replacement can be carried out in the shortest possible time with extremely little effort.

Firing manufacture economically

The BG OptiFeed is a screw conveyor with load cells. This allows the material to be fed continuously.

Cement manufacturers face strict environmental regulations with alternative fuels. This way, they fire calciners and main burners in an efficient and sustainable manner. BEUMER Group develops single-source solutions in order to convey, store and feed the differently composed materials. Among other things, the overall systems are made up of specially developed individual components.

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Cement is the most commonly used building material worldwide, and is continuously growing. However, manufacturers have to comply with ever stricter environmental regulations in order to get air pollution under control. Depending on the processes used, the emissions from producing cement are at 0.6 to 0.99 t of CO_2 per ton of cement. The CO_2 emissions from this sector are estimated to account for seven to 8% of the overall global carbon dioxide emissions. An approach to sustainably reduce greenhouse gas emissions and production costs is to increase the use of alternative fuels.

Fluid materials like waste oil or solvents but also solids for example are used instead of coal and gas. The majority is here composed of municipal and industrial waste, such as plastic, paper, composite material or textile mixes as well as wood pellets. The use of entire or shredded waste tyres is also welcome. The calorific value of the rubber from waste tyres is comparable to that from hard coal, and the iron from the reinforcement can be incorporated mineralogically into the cement. This minimises the addition of ferrous corrective substances. Alternative fuels are available in large quantities and at low costs and can be disposed of completely in a safe high-temperature process in the rotary kilns at the cement plants. Thus, these materials do not have to be landfilled or otherwise disposed of.

As different materials have different calorific values, the complete household waste cannot simply be fed into the combustion process in the kiln. Especially in countries where waste separation is not developed like in Europe, the challenge is huge. How the alternative fuels are composed and how they are used often also depends on their availability in a determined region and, in particular, on the economic aspects. In addition, the materials have to fulfil determined quality requirements. Some operators for example only use processed waste with a defined minimum calorific value and low heavy metal content. At this regard, the alternative fuel often may only have a determined particle size and a determined density. The moisture content is also important.

BEUMER GROUP SUPPLIES INDIVIDUAL SINGLE-SOURCE SOLUTIONS

The BG OptiBulk unloading station is equipped with a special housing, which protects the environment from dust escape and the material from environmental stress.

Inside of a U-shape conveyor.

FROM THE RECEIVING TO THE FEEDING PROCESS

As a system provider, BEUMER Group develops tailor-made solutions for the entire material flow chain from unloading the delivery vehicle to storing, weighing, conveying and control feeding of solid alternative fuels. BEUMER Group also provides fully automated systems that can control feed, singulate and convey large and heavy tyres to the inlet of the rotary kiln. BEUMER Group supports the cement manufacturers with its intralogistic solutions in modernising their plants in sustainable and cost-efficent ways. "Our know-how and tailor-made systems permit us to optimise our customers' processes," says Jan Tuma, Chief Sales Officer (CSO), BEUMER Group, Czech Republic. The user receives everything from one source, thus having a unique contact. In addition to a comprehensive range of reliable systems for handling with alternative fuels, the specialists also focus on planning logistics and customised conveying and storage solutions, including crane halls and steel structures.

CLEAR UNIQUE FEATURE

"The material flow chain is implemented with the single components of our BG OptiSeries," says Jan Tuma. "We have developed these different systems in our company – a clear unique feature on the market". The systems are designed to meet the requirements for functionality and performance in daily operation.

The material prepared for combustion in the kiln is usually supplied in moving-floor trailers. The hydraulically controlled moving floor moves the load outwards on the conveying system. "All conveying systems supplied and the accompanying equipment are intertwined like toothed gears to ensure steady fuel feeding," explains Jan Tuma. "At this regard, we can install our unloading station BG OptiBulk at our customers". This system is suitable for inhomogeneous material that is difficult to handle. Such materials have a low bulk density, a high moisture and a large grain size. In addition, this system is suitable for explosive substances. In addition to tippers and moving-floor trailers, which are sometimes in use, trucks can also be unloaded quickly and easily. The system consists of a chain belt conveyor and lateral steel walls.

A further possibility to empty trucks and moving-floor trailers is given by the BG OptiDock. This station is also suitable for inhomogeneous material like alternative fuels or biomass. The BG OptiDock is composed of a receiving box and a screw floor. It guides the raw materials and the alternative fuels coming from the moving-floor trailer and the truck on a feeding system. The receiving box is equipped with a rubber gasket and, if necessary, with an hydraulic pump in case that the vehicle is not available. It permits to unload the semi-trailer continuously.

The double discharge screw conveyor of the BG OptiLock construction series: The airlock principle protects the material against the infiltrated air entering from outside.

BEUMER GROUP SUPPLIES INDIVIDUAL SINGLE-SOURCE SOLUTIONS

U-shape conveyors can be simply integrated and are also suitable for horizontal and vertical curves.

The material falls from the unloading station into the BG OptiFeed screw weigh feeder with a connected buffer bin. This screw conveyor with weighing cells is suitable for completely different materials – that means, ideal for the continuous feeding of alternative fuels or raw materials," says Jan Tuma. Since the screw conveyors are positioned on the weighing cells, it can always be seen how much material is extracted. The regulation ratio is max. 1:10 and the maximum feeding accuracy between 1% and 2%," explains Jan Tuma. In addition, the completely closed screw weigh feeder is protected against dust.

BEUMER Group also offers a BG OptiFeed Duo. This solution has been designed for the continuous feeding of bulk material to two separated feeding points in one process, for example when the preheater tower has two inlets. The material is then stored in a buffer bin and taken off by two single screw conveyors or one double screw conveyor.

Pipe Conveyor: The enclosed system ensures an environmentally safe, dust-free and low-energy transport of the alternative fuels.

CONVEYING TECHNOLOGY IN TUBULAR SHAPE OR U-SHAPE

In order to transport the alternative fuels to the calciner and to the main burner, BEUMER experts, depending on the application, evaluate different variants of mechanical conveying systems, which for example include the Pipe Conveyors. "This conveying technology is not only eco-friendly and requires low maintenance", describes Jan Tuma. "Its enclosed type of construction also protects the environment safely from material falling down and emissions. Another advantage is the elimination of dust development on the running line". Due to its ability to navigate curves, considerably fewer transfer towers are required compared to other belt conveyors and the system can be customised to the individual routings. "If necessary, we can further equip the conveyor," says Jan Tuma, "for example with a scraper conveyor in order to minimise clean-up, or with a dedusting filter".

A further efficient possibility is the U-shape conveyor. It can be simply integrated and is also suitable for long distances and rough terrain as well as horizontal and vertical curves. Just like in the Pipe Conveyor, the material conveyed is protected against external influences such as wind, rain or snow and the environment against possible material loss. This conveying solution is suitable for coarse but also for very fine material.

"At the feeding point, the U-shape conveyor is open like conventional troughed belt conveyors," explains Jan Tuma. "A special idler configuration brings the belt in a U-shape". This way the material conveyed reaches the discharge station. An idler configuration similar to that for the shaping is used for opening the belt.

REDUCES INFILTRATED AIR TO THE CALCINER

Conveying elements lead the material to the discharge screw conveyors of the BG OptiLock construction series. The airlock of this system solution protects the pyroprocess from the infiltrated air, i.e. the air that additionally and uncontrollably enters from the outside with the fuel. Also the BG OptiLock is equipped with load cells and transfers the bulk material continuously to a screw conveyor, which feeds the calciner. The speed of the discharge screw conveyor is controlled so that the shown weight of the entire system and the real material volume in the container is constant. "As the material can catch fire, all systems are carried out according to the ATEX directives," says Jan Tuma.

As a single-source provider, BEUMER Group has substantial competence in handling with alternative fuels and is able to support the owners of cement plants efficiently – all within a short period of time. All components are complementary and ensure the continuous and economical feeding with alternative fuels.

BEUMER Group is an international leader in the manufacture of intralogistics systems for conveying, loading, palletising, packaging, sortation, and distribution. With 4,500 employees worldwide, BEUMER Group has annual sales of about EUR 960 million. BEUMER Group and its group companies and sales agencies provide their customers with high-quality system solutions and an extensive customer support network around the globe and across a wide range of industries, including bulk materials and piece goods, food/non-food, construction, mail order, post, and airport baggage handling.

For more information visit www.beumer.com.

Weir Minerals' Enduron® HPGR provides a glimpse of the mine of the future

The significant reduction in energy consumption High Pressure Grinding Rolls (HPGRs) deliver miners – up to 40% in the case of Weir Minerals' Enduron® HPGR – is rightly the thing that captures most people's attention. It is uncommon, after all, that a single piece of technology offers such radical improvements compared with more established, widely employed technologies.

As Weir Minerals continue to grow its install base, it is finding that – while operators are often drawn to the Enduron® HPGR for its energy saving potential – it's rarely the first thing they notice. Indeed, Weir Minerals' team of engineers bring unrivalled process knowledge and do a mountain of work before the Enduron® HPGR is installed to ensure it meets specification and, in the case of brownfield integration, does not affect existing production. While this solutions-focused approach is essential to delivering the outstanding results the Enduron® HPGR has become recognised for, the expertise and experience Weir Minerals brings to these projects is often overlooked.

At the same time, as the regulatory market tightens with regard to greenfield projects, this experience and knowhow has never been more valuable as miners seek to optimise their brownfield operations.

CAPITALISING ON OPPORTUNITIES

It is a very exciting time for the mining industry. The transition to a low carbon economy powered by electrification has seen a significant growth in the demand for battery metals. The intensification of environmental policies and willingness of the sector to be more sustainable, while playing a constructive role in efforts to decarbonise has seen many miners embrace more energy efficient technologies. And comminution, which accounts for up to 3% of total global energy consumption, is an obvious process to target.

Traditionally, HPGRs have been primarily selected in hard rock, high volume applications, like gold and copper. Current demand for these minerals is creating high commodity prices; however, the 'all-in sustaining costs' to recover the valuable metals is increasing significantly too. For these reasons, along with ESG driven arguments, there is an onus on miners to invest in new technologies with the aim of reducing their operating costs. And while the immediate benefits are substantial, these technologies are an investment in the future; while commodity prices may fluctuate and capital costs rise, the Enduron® HPGR's efficiency is assured and can be relied upon.

There is also growing demand for battery metals, as well as more future-focused commodities, like potash.

At the same time, supply chain disruptions have emphasised the importance of products and equipment that can deliver high availability.

All this, in other words, bodes well for miners who have invested in efficient, effective and reliable comminution equipment, like the Enduron® HPGR.

COMMINUTION SOLUTIONS

There are, of course, many regional and application-specific factors – energy and water prices and climatic conditions, for instance – that determine the ideal comminution solutions for each operation.

Outside traditional hard rock applications, HPGRs may not always be the most suitable solution; however, Weir Minerals is seeing a willingness from across the mining industry to explore innovative, creative flowsheets as a way of reaping the efficiency benefits of the Enduron® HPGR.

This is a challenge Weir Minerals has embraced. It has a large, well resourced team to support operators with their modelling questions and flowsheet optimisation projects.

Miners have the opportunity to come to Weir Minerals' technical centres and see the Enduron® HPGR in action; they are able to experience firsthand how its effective grinding improves mineral liberation, delivering higher recovery rates. And, as these results become tangible, the technology is validated.

BROWNFIELD OPTIMISATIONS

The benefits the Enduron® HPGR can deliver become less abstract with demonstrative examples of brownfield optimisations in which the technology can be compared against incumbent technologies.

In a large brownfield gold circuit, which has been recently commissioned, Weir Minerals will be replacing the full tertiary cone crusher circuit consisting of five crushers with a single Enduron® HPGR, which will process around 4,500 tonnes per hour and increase gold recovery by 4%. The operating costs will also be reduced because maintenance, rather than having to be carried out on multiple cone crushers, will only have to be carried out on a single unit.

This success provides a glimpse of what is possible in greenfield projects where there is more scope to tailor solutions to the operator's requirements and the site's specific challenges. At Iron Bridge, a magnetite project in Australia, Weir Minerals helped design a flowsheet that involved a multi-stage HPGR circuit, including air classification, which allowed for inter-stage rejection of around 20% of the waste material. This reduces wear on the equipment, improves efficiency and has associated tailings management benefits too.

The design philosophy that underpins the Enduron® HPGR lies at the heart of why it outperforms not only traditional crushing and grinding equipment, but also competitor HPGRs.

CAPITALISING ON OPPORTUNITIES: WEIR MINERALS

DESIGN PHILOSOPHY

Traditionally, HPGR manufacturers have shied away from skewing designs, for fear of roller misalignment creating unfavourable load distributions and preventing the use of flanged guards to reduce the edge effect. However, the Enduron® HPGR's unique roller bearings design allows for skewing alongside effective self-adjusting cheek plates, reducing wear and promoting better grinding.

Skewing ensures that pressure is distributed across the full width of the tyre, minimising recirculation. This is particularly applicable in segregated feed conditions, which are typical in mineral processing applications. The Enduron® HPGR can dynamically accommodate these changing feed conditions through skewing, allowing for the passage of oversized crushing material and tramp metal, resulting in less downtime.

In order to accommodate this uneven pressure, Enduron® HPGRs utilise a unique spring-loaded cheekplate that has been specifically designed to facilitate roll skew and reduce the edge effect. Put simply, it maintains an even pressure distribution across the entire feed, saving energy and reducing wear.

Another unique feature of the Enduron® HPGR is the protective bearing arrangement that's been designed to protect against premature failure and reduce the number of peak loads that can be transferred to the bearings.

Enduron® HPGR's are supplied with a multi-row cylindrical roller bearing system and a Weir Minerals bespoke tailored rubber thrust pad that's arranged directly in front of the bearing housings. This unique design ensures the bearings are always parallel with the shaft, mitigating the peak pressures and bearing contamination. It also allows for oil lubrication to the main bearings, which delivers market leading bearing life with proven performance guarantees in excess of 100,000hrs.

The Enduron® HPGR's roll length:diameter (L:D) ratio delivers the highest product quality, minimising recirculation and reducing operational costs. It enables smaller tyre diameters for a given tonnage relative to all competitors. This optimises the operating gap, ensuring full pressure across the full tyre length, exceeding the ore's compressive strength. This superior L:D ratio and compact cylindrical bearing arrangement means that Enduron® HPGR operators enjoy significantly reduced infrastructure costs as the required civil structural height is kept to a minimum.

END-TO-END DIGITAL SOLUTIONS

The aforementioned features and product enhancements are the way OEMs have traditionally sought to provide value to operators. However, while recognising the centrality of this approach to its business, Weir Minerals also wants to be a digital end-to-end solutions provider to its customers. In other words, it wants to offer its customers a level of complexity and analytic detail that goes beyond what condition monitoring systems typically provide.

Weir Minerals' Synertrex® digital ecosystem is paving the way for the future 'connected' mine. The key to the success of 'connected' mines rests on gaining access to multiple sources of information, an emphasis on smart data and a commitment to holistic intelligent platforms. Driven by advanced digital technologies, the Synertrex® digital ecosystem improves equipment performance, abates emissions and reduces component wearing, eliminating unexpected breakdowns and maximising productivity.

Fast evolving IIoT technologies – together with advanced data processing techniques that utilise artificial intelligence, machine learning models and neural networks (i.e. a series of algorithms that endeavour to recognise underlying relationships in a set of data through a process that mimics the way the human brain operates) – are driving a shift towards a more proactive approach to both maintenance planning and execution, resulting in unprecedented plant optimisation.

Traditionally, when operators talk about digitally optimising a HPGR's reliability they are referring to the application of a condition monitoring system to add a degree of predictability. For example, sensors may monitor wear on the tyres and cheekplates to ensure they are replaced at the ideal time. Similarly, sensor data improves operational visibility and helps provide a better understanding of skewing performance.

As an OEM, Weir Minerals has exclusive access to Enduron® HPGR design data, maintenance histories and performance data, which significantly enhances the Synertrex® digital ecosystem's capabilities.

Having all this data and supporting information in a single environment is what drives the training of machine learning models, which in turn makes artificial intelligence possible through a series of neural networks, analysis of relational event dependencies and the probability of root causes. In turn, this drives automated and accurate decision support recommendations in which suggestions or prompts are provided to support human intervention. Other useful information – like remaining useful life through predicative analytics can be extracted and condition-based maintenance strategies can be implemented to drive overall equipment effectiveness (OEE). This is how predictive maintenance becomes a dynamic tool.

Weir Minerals is investing in a future in which the 'connected' mine will combine intelligent data from multiple equipment levels. In other words, the Enduron® HPGR will intelligently and autonomously communicate and interact with upstream and downstream equipment, like the mills and crushers, to enhance the overall process performance, not just the HPGR.

PAST, PRESENT, FUTURE

Mining is one of the oldest industries in the world – it has been a major social and economic force throughout history. The mining of yesteryear barely resembles what happens today; in a similar vein, the mining of the future will look equally as unfamiliar and rudimentary. But change and progress happen incrementally and that is what Weir Minerals – with its Enduron® HPGR and Synertrex® digital ecosystem – is trying to advance. The world needs smarter, more efficient comminution.

Optimising fragmentation for downstream process efficiency

Elevation view of Warren County's crusher dump pocket.

The primary crusher is one of the most critical facilities in a quarry operation as it dictates the site's throughput. The crusher, however, is also one of the most power-hungry systems that break down rocks into sizes as small as 25mm. This process inherently requires a significant amount of energy, and operators are constantly looking for ways to optimise their crushing circuit to maximise throughput with minimal power consumption.

MEASUREMENT TECHNIQUES AND CHALLENGES

Feeding the crusher with rocks of a specific size is essential to maximise performance and energy efficiency, and blasting is currently the most common way to break down the rocks.

Conventionally in quarry operations, fragmentation is measured in an ad-hoc manner with photogrammetry or 2D image solutions that require operators to take images of the muck pile or at the back of a haul truck using drones. These activities are typically manually intensive and costly and yet do not provide enough data for operators to understand the fragmentation distribution across a blast. Hence the key to improving crushing operations performance is first to achieve the optimal blast fragmentation.

Fortunately, this is about to change as Orica recently unveiled its latest pre-crusher fragmentation monitoring solution, enabling operators to improve productivity through fragmentation profile analysis and blast optimisation for downstream impact.

AN AUTOMATED PRE-CRUSHER FRAGMENTATION MEASUREMENT TOOL THAT DELIVERS OPERATIONAL CONTINUITY

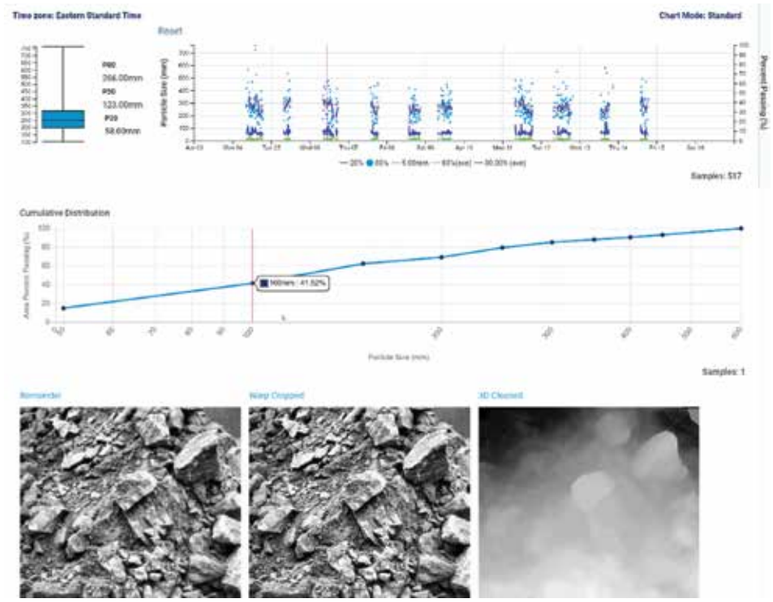
Orica's FRAGTrack™ is a state-of-the-art fragmentation measurement tool that leverages the latest deep neural network artificial intelligence (AI) framework along with industry-proven hybrid 2D and 3D particle size distribution (PSD) processing methods to deliver a fully autonomous adaptive fragmentation monitoring solution at the crusher dump pocket, enabling customers to measure material on the truck during the tipping operations.

(Front) FRAGTrackTM System – F60 component houses various measurement sensors used in the determination of PSD samples. (Back) F50 component houses the edge computer processing and communication technologies used by the system.

FRAGTrack™ Crusher provides truck by truck PSD analysis of rock fragments during the dumping operation with unmatched accuracy and without impacting operations or productivity. PSD data is provided via a real-time application programming interface (API) and industrial open platform communication unified architecture (OPC UA) protocol to drill and blast software and crusher distributed control systems (DCS), allowing seamless integration into the existing site operation workflows.

The technology delivers constant performance tracking for both the drill and blast operations and the downstream processing functions, driving continuous improvements in the mining value chain.

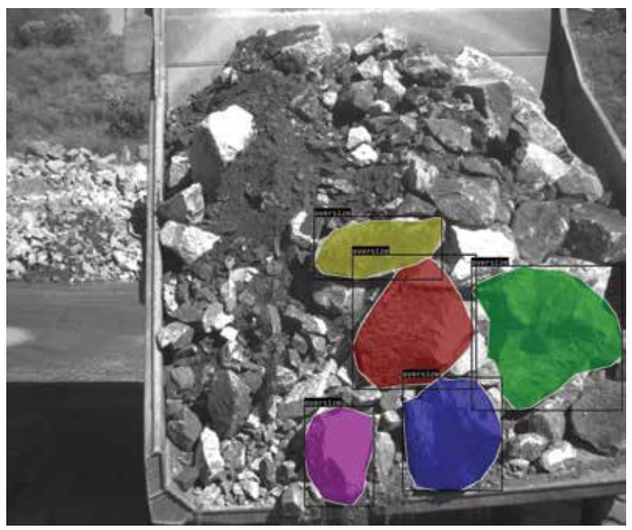
The FRAGTrack™ Crusher mounted installation (Visualisation).



FRAGTrack™ Web dashboard showing the PSD at the crusher for a particular blast

CASE STUDY – OPTIMISING FRAGMENTATION FOR DOWNSTREAM PROCESS EFFICIENCY

MidSouth Aggregates' Quarry in Warren County, Georgia, is a rail-served quarry providing granite products that meet various construction needs, including riprap, railroad ballast, concrete and asphalt products, and general construction aggregates. It produces aggregates for infrastructure applications such as asphalt and railroad ballast. The large rock body comprising the property is highly jointed and seamed, making it challenging to design blasts that consistently produce aggregate close to the economically optimal band of ¾ - 2-inch material. Without meticulous blast designs, blasts will produce excessive oversize or fine material, resulting in higher downstream processing costs and waste. Therefore, it is crucial for MidSouth Aggregates to continuously improve blast designs to produce a size distribution that minimises downstream costs.

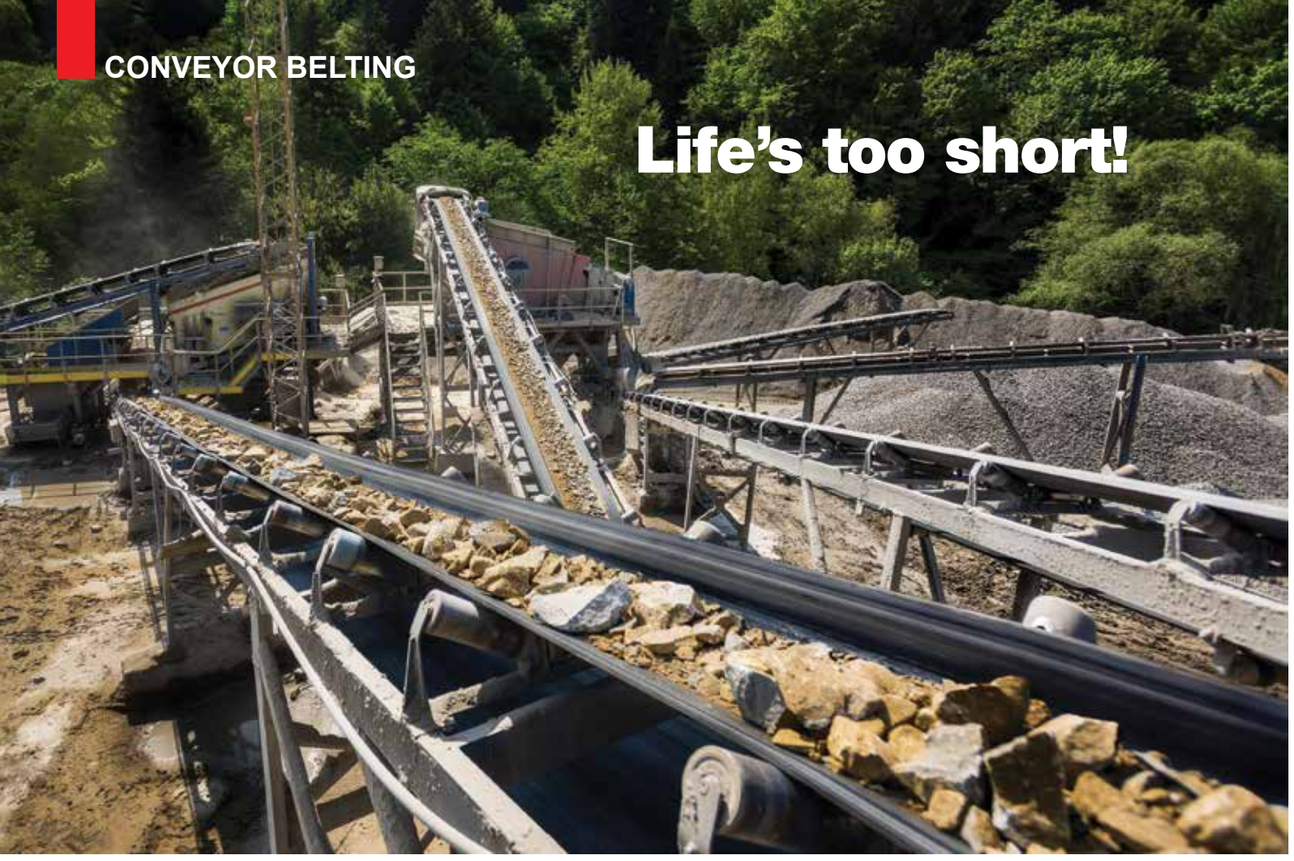


Oversize detection output example – alert can be set based on the size of the bounding box

The site currently uses FRAGTrack™ Conveyor and uses its web portal to view and analyse fragmentation measurement information. The dashboard provides a quick health check of the equipment deployed, and the measurement trends, while the detailed graphics provide timestamped measurements, sample images and consolidated PSD data. This information helps the drill and blast team correlate the blasting performance to the resultant fragmentation measurements. Armed with this information, the team does a weekly review of blasting performance vis-a-vis the fragmentation outcome and makes necessary corrections to the blasting parameters pertaining to the geology and rock formation at the site to yield the desired fragmentation.

When bundled with FRAGTrack™ Crusher, the site can analyse the crusher's performance and the impact of blasting parameters in a production workflow in real-time. Using images captured for PSD analysis, FRAGTrack™ leverages its deep neural network AI to build models and teaches the system to identify oversize rocks during the casting/dumping operation. This opens the possibility to send an oversize alert to the operation team via phone text messages or open platform communication (OPC UA) tags to send alerts/notifications to programmable logic controller (PLC) systems or other systems syndicated to the supervisory control and data acquisition (SCADA) system via OPC UA integration. Similarly, using the OPC UA integration, FRAGTrack™ can also send the PSD measurements directly to the plant automation systems (without any manual intervention) for continuously monitoring and correlating the fragmentation results to the rest of their downstream operations.

FRAGTrack™ Crusher has been deployed for over six months, providing MidSouth Aggregates direct feedback to measure the performance of their blasting practices in the resultant fragmentation and having a better correlation between fragmentation and their crusher performance. The next phase of the deployment is to introduce the oversize detection capability to notify the operator of any potential oversize on the truck before dumping it into the crusher. This will significantly improve the crusher throughput and monitor the continuous improvements of the site operation.



Life's too short!

The top five reasons why conveyor belts have to be replaced prematurely.

Although industrial conveyor belts are costly components, it is increasingly common to see belts being replaced much sooner than they really should be. Here, conveyor belt specialist Leslie David explains the top five reasons for the lack of longevity as well as providing some helpful tips on how to maximise belt life and reduce costs.

1. WRONG SPECIFICATION OF BELT

One of the most common reasons why so many belts fail to provide a long and cost-effective lifespan is simply that the specification of belt is not correct for the conveyor application and/or the materials and working conditions. This applies to both new conveyors and ones that may have been running for years. Not only may the belt calculation have been incorrect in the first place, what can also happen is that different belt specifications have been tried over the years, usually in an effort to reduce the frequency of repairs or simply to reduce the frequency of replacement. Ironically, the underlying cause of such problems is that the belts being used are simply not of an adequate standard.

Whatever, the case, selecting a conveyor belt involves making a complicated assessment of all available parameters such as the conveyor system itself including pulley diameters, transition distances, transverse rigidity and much more. Just as importantly, the materials to be conveyed, operational environments and health & safety considerations all have to be taken into account.

For new conveyors the first stage of any belt selection should involve the use of a belt calculation program overseen by a professional conveyor belt engineer. The same applies when a conveyor is proving to be problematic. Before any new belt is purchased and fitted, you need to be absolutely sure that the specification of the belt is correct.

The materials being conveyed are important to correct belt selection

CONVEYOR BELT QUESTIONNAIRE

Date : 1
Completed by : 2

Company name : 3
End-user : 4
Conveyor reference number : 5
Project name : 6

CONVEYOR BELT CURRENTLY INSTALLED

Total belt length : 7 m		Belt width : 12 mm	
Tensile strength : 8 N/mm		Number of plies/cords : 13	
Top cover thickness : 9 mm		Bottom cover thickness : 14 mm	
Cover/Belt quality : 10		Belt thickness : 15 mm	
Carcass material : 11 ☐ Textile ☐ Steel		Breaker type : 16 ☐ Textile ☐ Steel ☐ None	

CONVEYOR DETAILS

Conveyor centre-distance : 17 m		Max. inclination angle : 28 °	
Belt speed : 18 m/s		Capacity : 29 t/h	
Troughing angle (carry/return) : 19 ° / °		Tensioning system type : 30 ☐ Screw system/fixed ☐ Gravity take-up ☐ Hydraulic ☐ Spring loaded	
Idler spacing (carry/return) : 20 m / m			
Idler diameter (carry/return) : 21 mm / mm		Available take-up length : 31 m	
Head pulley diameter : 22 mm		Take-up weight : 32 kg	
Tension pulley diameter : 23 mm		Location tensioning system : 33 ☐ at ☐ head ☐ tail ____ meters from head	
Tail pulley diameter : 24 mm		Length of skirting boards : 34 m	
Bend pulley diameter : 25 mm		Number and type of scrapers : 35	
Snub pulley diameter : 26 mm		Tripper car height, if any : 36 m	
Total material lift : 27 m		Tripper pulley diameter (discharge/bend) : 37 mm / mm	

The first stage of any belt selection should involve the use of a belt calculation program overseen by a professional conveyor belt engineer.

It is just as easy to over-specify a belt as it is to under-specify. Over-dimensioned belts can create all kinds of problems, especially if the tensile strength or the number of plies exceeds what is actually necessary. First of all, the belt will be heavier and less flexible in both length and width than it should be. Reduced longitudinal flexibility usually requires an increase in the diameter of the drive pulley. A tensile strength that is just one step too high would usually necessitate an increase in diameter of 25% or more. Failure to increase the pulley (drum) diameter can lead to dynamic stress failure, especially in splice joint areas. Reduced horizontal flexibility causes a decrease in troughability.

2. INADEQUATE WEAR RESISTANCE

The wear resistant quality of the outer covers of a conveyor belt is the biggest single influence on the working life of the belt and consequently its 'whole life' economic cost. The choice of cover grade or 'cover quality', is primarily influenced by the materials being conveyed, closely followed by the operational conditions. In the world of quarrying and mining, the most common requirements are the ability to resist abrasion, ripping, tearing and impact.

The rubber used for the outer covers usually constitutes at least 70% of the overall volume mass of both multi-ply and steelcord belts and 50% of the raw material costs. This makes it the single biggest opportunity for manufacturers to minimise costs and to compete for orders based on price rather than quality and performance. It is a common misconception that a belt specified by a supplier as being 'abrasion resistant' should be expected not to wear quickly.

Different causes of wear and abrasion require different kinds of abrasion resistant rubber. For example, belts that transport heavy and/or sharp objects such as rocks, which cut and gouge the belt surface need different resistance properties compared to belts carrying 'fine' materials such as aggregate, sand and gravel, which literally act like a piece of coarse sandpaper that is constantly scouring the belt surface.

Abrasion resistance – International standards

There are two internationally recognised sets of standards for abrasion, EN ISO 14890 (H, D and L) and DIN 22102 (Y, W and X). In Europe the longer-established DIN standards are most commonly used. Typically, DIN Y (ISO 14890 L) relates to 'normal' service conditions such as sand and gravel. In addition to resisting abrasive wear, DIN X (ISO 14890 H) also has good resistance to cutting, impact and gouging such as sharp, heavy rocks. DIN W (ISO 14890 D) is usually reserved for particularly high levels of abrasive wear often found in crushers for example.

The most important thing to remember when comparing abrasion test results is that higher figures represent a greater loss of surface rubber, which means that there is a lower resistance to abrasion. Conversely, the lower the figure the better the wear resistance. Comparing the wear resistant capabilities of one offer with another is not always easy because (with only one exception that I know of) technical datasheets provided by manufacturers and traders only show the minimum figure demanded by a particular test method or quality standard rather than the actual performance that the belt should be expected to achieve.

Different causes of wear and abrasion require different kinds of abrasion resistant rubber.

The wear resistance of rubber is a combination of overall strength, resistance to abrasion and resistance to cut and tear propagation.

It is also important to bear in mind that the ability of a belt cover to withstand wear is not due to its 'abrasion resistance' alone. The wear resistance of rubber is a combination of its overall strength, its resistance to abrasion and its resistance to cut and tear propagation. If the latter is very low then a small, seemingly insignificant area of damage in the cover can easily increase due to the continuous material loading and the relentless flexing of the rubber around the drums and pulleys. In time, this damage will connect to another area of damage and consequently a small piece of damaged rubber will effectively be cut out and lost rather than simply worn off.

A final word on wear resistance – whatever cover grade you use, it is absolutely essential that the rubber is fully resistant to the effects of ozone and ultra violet. At ground/sea level ozone becomes a pollutant. Exposure is unavoidable. It increases the acidity of carbon black surfaces and causes reactions to take place within the molecular structure of the rubber resulting in surface cracking and a marked decrease in its tensile strength.

Likewise, ultraviolet light from sunlight and artificial (fluorescent) lighting also accelerates deterioration because it produces photochemical reactions that promote the oxidation of the surface of the rubber resulting in a loss in mechanical strength. In both cases, this kind of degradation causes the covers of the belt to wear out even faster than they should. In my experience, belts imported from South East Asia will almost certainly not be resistant to ozone and UV. My advice is therefore to make ozone & UV resistance an essential part of the specification when selecting any rubber conveyor belt.

Ozone & ultra violet light causes rubber to literally disintegrate.

3. DAMAGE – RIPPING, TEARING AND IMPACT

As every site manager will know, when foreign objects become trapped, penetrate the carcass and cause longitudinal ripping, even the strongest, heaviest belts can be quickly destroyed. The same applies when a belt is torn or the carcass is punctured by heavy, sharp materials falling from height. It is something that all conveyor operators have to contend with. Believing that such damage is unavoidable and trying to save money by fitting low grade 'sacrificial' belts is certainly not the answer. Using 'throwaway' belts is a false economy and simply does not make economic sense, especially when you calculate the cost of frequent repairs and total belt replacement plus the cost of downtime while that work has to be carried out.

In quarrying and mining, the ability to withstand the forces that rip and tear belts is often more important than any other physical attribute.

Despite its significance as a key performance indicator, there are currently no internationally accepted test methods or standards for testing rip resistance, which is perhaps one reason why belt manufacturers rarely mention the subject. Fortunately, an international standard for tear strength does exist. The ISO 505:2017 test method measures the

Even the strongest belts can be ripped, torn or punctured by sharp foreign objects.

Ripping, tearing and impact – the best solution is to fit a conveyor belt specifically engineered for the purpose.

propagation resistance of an initial tear in textile conveyor belts, either in full thickness or of the carcass only. The test is intended for application to multi-ply (fabric) belts in installations where there is a risk of longitudinal tearing. Although it is a defined method of testing, there are no standardised performance requirements.

Engineered for the task

Because of the huge disparities between the types of materials being conveyed, the actual design of the conveyor systems and their varied working environments, there is no 'silver bullet' answer to the rip, tear and impact damage. For multi-ply belts the only genuinely practical solution is to fit a conveyor belt that has been specifically engineered to resist ripping and tearing and cope with the impact of heavy objects such as large rocks falling from a high drop height much more effectively compared to belts that use a conventional fabric ply construction. Specially woven fabric plies that allow the transversal nylon strands to stretch are used to create a much greater level of resistance. As the trapped object is pulled through the belt, the transversal (weft) strands of the fabric group together into a bundle that can eventually become strong enough to stop the belt. Strange as it may seem, these special synthetic plies are usually more effective than steel when it comes to actually minimising the length of a rip. Another important feature of such specialist fabrics is the ability to absorb punishment caused by heavy impact by dissipating the energy over a wider area compared to conventional fabric.

The good news is that specialist belts of this kind are produced here in Europe but beware of cheap imitations. The genuine article has at least three or more times the resistance to ripping and tearing compared to conventional belt as well as being amazingly resistant to abrasive wear at the same time. As a result, they will quite literally run for many years, even on conveyors where conventional belts regularly need to be replaced at extremely short intervals. There is a higher initial price to pay of course but their cost over their working life is considerably lower and with the added benefit of far fewer unplanned stoppages for repairs.

4. CARCASS FAILURE

Although carcass failure is commonly seen as a reason for premature belt replacement in its own right, there are a number of different causes of carcass failure that could also quite legitimately be categorised as wrong specification of belt (reason one) and accidental damage (reason three).

When there are impact damage and/or ripping and tearing problems, there is often the temptation to fit a belt with a higher tensile strength and/or a belt with an increased number of plies that is over-dimensioned for the conveyor design. An example that I came across very recently was where a 1000/5 belt had been fitted to a 55 meter primary conveyor in a quarry handling Gabbro stone. Despite the apparent added strength, the belt was still only lasting an average of 600 hours. The same 'solution' is often attempted when there are problems such as too much elongation (stretch) or repeated splice failure. To be fair, provided the design of the conveyor allows it, increasing the tensile strength can be worthwhile but only if the damage to the current belt is due to insufficient load support or if the belt was obviously under-specified in the first place.

As I mentioned earlier, simply increasing the tensile strength or the number of plies can cause more problems than it solves. I would strongly advise getting a completely new belt calculation using a professional belt calculation program before you consider any change of belt specification. If you have a piece of spare belt available then it is often a good idea to send a square meter of it for laboratory testing to measure its true tensile strength.

There are two reasons why this is advisable. In belts that have low quality (low cost) fabrics, it is unusual to find a fabric that has inadequate tensile strength. However, although the amount of material used in the longitudinal strands of the fabric may be adequate, the amount of transversal weft material is often kept to an absolute minimum in order to reduce cost. Although the required tensile strength might be achieved, rip and tear resistance is reduced and elongation (stretch) is low. Low elongation may sound good in principle but if the elongation is too low then this can cause problems with transition distances and a general inability to accommodate the contours of the conveyor and its drums and pulleys. Ultimately, this can lead to the premature failure of the belt.

The second reason for checking the true tensile strength of a belt before replacing it is that it is becoming increasingly common for some manufacturers, traders and importers to supply belts that have totally polyester (EE) fabric plies in a carcass that is declared as being an EP (polyester/nylon mix) carcass construction. The simple reason for this deception is

It is a good idea to have a piece of spare belt laboratory tested to measure its ***true*** properties.

Not what they seem – some belts are supplied totally polyester (EE) fabric plies in a carcass declared as being an EP (polyester/nylon) carcass.

that EE fabric costs some 30% less than EP fabric. In itself, this may not seem like a great deal but the fabric plies are a major cost component in any multiple ply conveyor belt so using the much cheaper polyester fabric is a big help when trying to achieve the perception of a lower 'like for like' price.

The whole basis of using a mix of polyester and nylon fabric is that it has the best balance of mechanical properties including allowing a conveyor belt to run straight and true, to trough, to flex round pulleys and drums, stretch, transversal rigidity, longitudinal strength and much more besides. The use of totally polyester (EE) fabric compromises a whole range of essential mechanical properties*. The biggest danger is that a polyester weft can cause low transverse elasticity, which reduces both the troughability and impact resistance of the belt and also causes tracking issues.

*(*Author's note: The use of fabrics made entirely of polyester (EE) has its place in certain belt types and constructions. However, in those cases the declared specification of the belt should clearly be EE and not EP).*

5. INADEQUATE CONVEYOR MAINTENANCE

To my mind, of all the causes and reasons for belts not achieving the length of operational life that they should, poor maintenance is the most careless and inexcusable. As with using 'cheap' sacrificial belts, failing to carry out routine checks and maintenance on a regular basis is a false economy. I often see conveyors operating with badly worn lagging, missing or damaged idlers and seised rollers, all of which can result in damage to the belt. Likewise, material build up beneath drums and pulleys is another common sight, often as a result of carry back.

The whole question of conveyor maintenance is a subject in its own right. However, as simple as it might sound, a daily visual inspection of all the idlers, rollers, pulleys and drums is time well spent. Identifying and fixing problems at an early stage will certainly save on more costly repairs and maintenance later and with far less downtime. It will also help to keep your conveyors operating smoothly and your conveyor belts running trouble-free for periods that are much longer than you might ever have thought possible.

EXPECTING LESS MEANS GETTING LESS

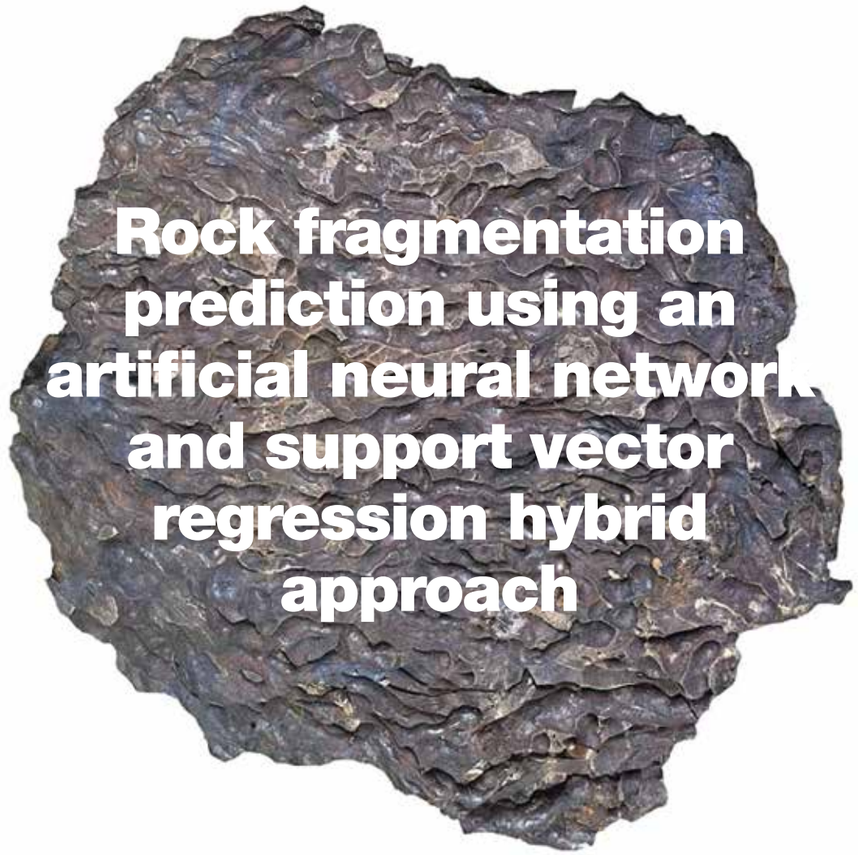
Thanks to years of technological advances and development, the effectiveness and value of modern day conveyor belts should be measured over several years rather than just a year or two or even just a few months, as is so often the case nowadays. It is no coincidence that the decline in the level of expectation has been accompanied by the increased use of low-grade belting, especially belt manufactured outside of Europe. The driver, of course, is the desire to reduce expenditure. However, belts that need frequent replacement have exactly the opposite effect. Expecting less means getting less for your money. The results of low quality remain long after the sweetness of low price is forgotten.

Identifying and fixing problems early will save on more costly repairs later.

ABOUT THE AUTHOR

Leslie David

After spending 23 years in logistics management, Leslie David has specialised in conveyor belting for over 16 years. During that time, he has become one of the most published authors on conveyor belt technology in the world.



Rock fragmentation prediction using an artificial neural network and support vector regression hybrid approach

While empirical rock fragmentation models are easy to parameterise for blast design, they are usually prone to errors, resulting in less accurate fragment size prediction. Among other shortfalls, these models may be unable to accurately account for the nonlinear relationship that exists between fragmentation input and output parameters. Machine learning (ML) algorithms are potentially able to better account for the nonlinear relationship. To this end, we assess the potential of the multilayered artificial neural network (ANN) and support vector regression (SVR) ML techniques in rock fragmentation prediction. Using geometric, explosives, and rock parameters, we build ANN and SVR models to predict mean rock fragment size. Both models yield satisfactory results and show higher performance when compared with the conventional Kuznetsov model. We further demonstrate an automated means of analysing a varied number of hidden layers for an ANN using Bayesian optimisation in the Keras Python library.

INTRODUCTION

Rock fragmentation is the process by which rock is broken down into smaller size distributions by mechanical tools or by blasting. The resulting fragment size distribution may be characterised by a histogram showing the percentage of sizes of particles, or as a cumulative size distribution curve[1]. The primary means of rock fragmentation in mining is blasting. A good blast produces a size distribution that is well suited to the mining system it feeds, maximises saleable fractions, and enhances the value of saleable material[2]. Blasting efficiently saves significant amounts of money that would otherwise be spent on secondary blasting[3]. It also yields significant savings on the costs of downstream comminution processes, ie crushing and grinding.

The results of a blast depend on several parameters, which are broadly categorised as controllable and uncontrollable[4,5]. Controllable parameters can be varied by the blasting engineer to adjust the outcome of blasting operations. Controllable parameters can be grouped into geometric, explosives, and time parameters. Geometric parameters include drill hole diameter, hole depth, charge length, spacing, burden, and stemming height. Explosives parameters include the type of explosive, explosive strength and energy, powder factor, and priming systems. Time parameters include delay timing and initiation sequence. A blasting engineer's ability to change these controllable parameters dynamically in response to as-drilled information is critical to achieving good fragmentation[3].

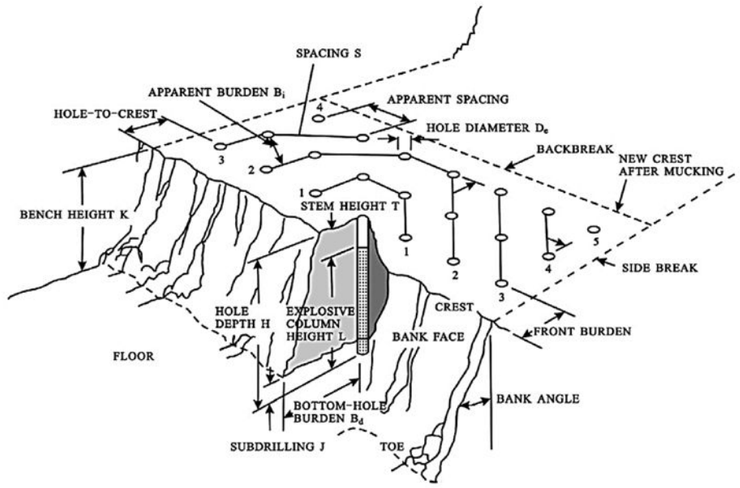


Figure 1: Blast design terminology[5].

The uncontrollable parameters constitute the geological and geotechnical properties of the rock mass. These parameters are inherent, and thus, cannot be varied to adjust blasting outcomes. They include rock strength, rock-specific gravity, joint spacing and condition, presence and depth of water, and compressional stress wave velocity[6]. Though these parameters cannot be varied by the blasting engineer, adequately accounting for them in a blast design helps to achieve good fragmentation. **Figure 1** is a bench blast profile showing a variety of design parameters.

Several studies have sought to predict fragment size distribution based on the parameters used in blast design. The accurate prediction will give blasting engineers control over the outcome of blasting operations. Consequently, engineers will know which controllable parameters to modify, and to what extent the modification should be. Having an accurate prediction model leads to good post-blast results, and this comes with enhanced loader and excavator productivity along with numerous downstream benefits. However, the prediction exercise proves to be challenging considering that numerous parameters influence fragmentation. Additionally, the rock mass may be heterogeneous and/or anisotropic in its structures of weakness. To this end, it is impossible to develop a predictive tool solely based on theoretical and mechanistic reasoning[5]. Researchers have thus mostly resorted to empirical techniques in predicting the outcome of fragmentation, with the Kuz-Ram being the most widely used. The empirical models are favored and widely used in daily blasting operations because they are easily parameterised. A major shortfall, however, with the empirical methods is that certain significant parameters are not accounted for, and this leads to less accurate results. Cunningham[2], notes that essential parameters omitted by empirical techniques include rock properties and structure, e.g., joint spacing and condition, detonation behavior, and mode of decking. Other parameters include blast dimensions and edge effects from the borders of the blast. Over the years, researchers have modified existing models and formulated new ones in an attempt to improve prediction accuracy. While this has contributed to significant improvement, none of the ensuing models incorporate all the important parameters, and accuracy is still of concern. In some instances, highly simplified or inappropriate procedures were used for estimating the properties of structural weakness in the rock mass[5]. Furthermore, the relationship between fragmentation input and output parameters is highly nonlinear, and empirical models may not be well suited for such modeling.

To this end, researchers, in recent years, have sought to implement machine learning (ML) techniques for fragmentation prediction. The objective was to capture as much of the inherent nonlinearity using limited input parameters and subsequently improve accuracy. Kulatilake *et al*.[5] and Shi *et al*.[7] have respectively exploited the potential of using artificial neural network (ANN) and support vector regression (SVR) for this purpose, and have achieved satisfactory results. ANN and SVR are machine learning techniques that are proven to possess high nonlinearity-recognition properties. However, ANN models in the rock fragmentation literature were limited to only one hidden layer, and do not exploit the potential of the multilayered network (ANN with more than one hidden layer), which could potentially lead to achieving higher accuracy. In this research, we implement SVR and a variety of multilayered ANN for predicting mean fragment size.

Machine learning (ML) is a branch of artificial intelligence (AI) that allows computer systems to improve their performance at a task through experience (learning) for the purpose of predicting future outcomes[7,8]. It is a multidisciplinary field that relies significantly on specialised subject areas such as probability and statistics, and control theory. ML techniques are broadly classified as supervised and unsupervised learning. Supervised learning is concerned with predicting an outcome given a set of input data. It does so by making use of the already established relationship between representative sets of input and output data that were used for model training. Unsupervised learning is concerned with data segmentation based on pattern recognition. Unsupervised ML techniques can infer patterns from data without reference to known outcomes. They are useful for discovering the underlying structure of a given data set. The rock fragmentation problem is a regression problem that is suited to tools of supervised machine learning such as multivariate regression analysis, artificial neural network (ANN), and support vector regression (SVR). The last two comprise algorithms that are more robust to nonlinear relationships between input and output data[5,9]. They are thus considered in this study since rock fragmentation input and output parameters are nonlinearly related.

PRELIMINARY BACKGROUND

We provide a fundamental explanation of the machine learning techniques used in this study. The section describes the architecture of the artificial neural network and support vector regression.

Artificial Neural Network (ANN)

Artificial neural network (ANN) is a machine learning technique that is inspired by the way the biological neural system works, such as how the brain processes information[7,8,10]. Information processing in ANN involves many highly interconnected processing elements known as neurons that work together to solve specific problems. The learning process involves adjustments to the synaptic connections existing between the neurons[7,11]. In the biological neural system, a neuron consists of a cell body, known as soma, an axon, and dendrites. The axon sends signals, and the dendrites receive these signals. A synapse connects an axon to a dendrite. Depending on the signal it receives, a synapse might increase or decrease electrical potential. An ANN consists of a number of neurons similar to human biological neurons. These neurons are known as units and are connected by weighted links that transmit signals from one neuron to the other[7,12]. The output signal is transmitted through the neuron's outgoing connection, which is analogous to the axon in the biological neuron. The outgoing connection splits into a number of branches that transmit the same signal. The outgoing branches terminate at the incoming connections (analogous to dendrites) of other neurons in the network[7].

An ANN has three types of neurons, and these are known as input, hidden, and output neurons. They are stacked in layers, and receive input from preceding neurons or external sources, and use this to compute an output signal using an activation function. The activation function is a mathematical formula for determining the output of a neuron based on the neuron's weighted inputs. The output signal is then propagated to succeeding neurons. While this is ongoing, the ANN adjusts its weights in order to record an acceptable minimal error between input variables and the final output variable(s)[13]. The complexity of the ANN architecture makes it well suited for solving both linear and nonlinear problems[10]. Advancement in computational power has enhanced its use in the fields of engineering, industrial process control, medicine, risk management, marketing, finance, communication, and transportation.

Suport Vector Regression (SVR)

Support vector regression (SVR) is a type of supervised machine learning that is based on statistical learning theory[14]. Just like the ANN, SVR is efficient at modeling nonlinearly related variables and does well at solving both classification and regression problems. It works by nonlinearly mapping, ie transforming, a given data set into a higher dimensional feature space, and then solving a linear regression problem in this feature space[9,15]. That is, it seeks to predict a single output variable ($\hat{y}$) as a function of n input variables (x) using a function $f(x)$ that has at most ε deviation from the actual values (y) for all the training data[16]. Equation 1 expresses this function in its simplest form as a linear relationship[9]:

Equation 1

$$f(x) = b + w \cdot \varphi(x)$$

In Equation 1, the function $\phi(x)$ denotes the high dimensional kernel-induced feature space. Kernel refers to the mathematical function used in the data transformation process. Different kernels are available for use in SVR analysis. They include the linear, polynomial, radial basis function (rbf), and sigmoid kernels. Parameter w in Equation 1 is a weight vector, and b is a bias term. Both w and b are calculated by minimising a regularised cost function. **Figure 2** is a graphical representation of the SVR concept. The $\pm\varepsilon$ deviation from the actual values (y) can be described as a tube that contains the sample data with a certain limit ε[16]. This implies that the function $f(x)$ is constrained by the $\pm\varepsilon$ limits to form a tube that represents the data set with the expected deviations.

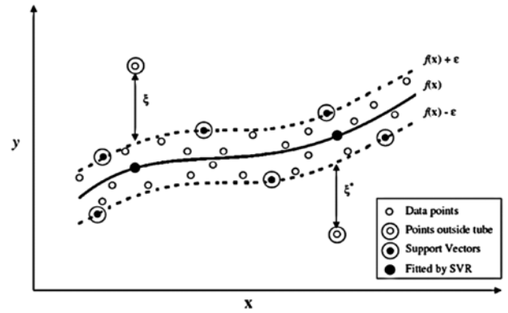


Figure 2: Graphical representation of support vector regression[17].

LITERATURE REVIEW

The ability to accurately predict fragment size distribution from a given blast design will give blasting engineers control over the outcome of blasting operations. Engineers will be able to identify which controllable parameters to modify, and to what extent the modification should be. To this end, several studies have sought to predict fragment size distribution based on the parameters used in blast design. These studies have resulted in empirical prediction models, with the Kuz-Ram being the commonest model in use. Others include the CZM, two-component model (TCM), Kuznetsov-Cunningham-Ouchterlony (KCO), SveDeFo, and Larson's equation[4,18]. The reliance on empirical models stems from the complexity that comes with the attempt to develop explicit theoretical and mechanistic equations to predict the outcome of fragmentation[2,4,5]. This complexity is primarily attributed to the fact that there are so many parameters that affect a blast, coupled with geological heterogeneity[5,9].

The Kuz-Ram model is essentially a three-part model consisting of a modified version of the Kuznetsov equation, the Rossin-Rammler equation, and the Cunningham uniformity index. The parameters defined by these equations constitute the output of the prediction model[4]. The Kuznetsov equation is for predicting mean fragment size (X50), and the original version is given by Kuznetsov[19] as:

Equation 2

$$X_{50} = A\left(\frac{V}{Q}\right)^{0.8} Q^{0.167}$$

In Equation 2, X_{50} is the mean fragment size (cm); A is the rock factor (7 for medium hard rocks, 10 for hard but highly fissured rocks, 13 for very hard, weakly fissured rocks); V is the rock volume (m^3); and Q is the weight of TNT (kg) equivalent in energy to the explosive charge in one borehole. A shortfall of the equation is that the rock mass

categories it defines are very wide, and thus need more precision[5]. Cunningham[20,21] provides a modified version of the equation as follows:

Equation 3

$$X_{50} = AK^{-0.8}Q^{\frac{1}{6}}\left(\frac{115}{RWS}\right)^{\frac{19}{20}}$$

In Equation 3, A is the rock factor, and varies between 0.8 and 22 depending on hardness and structure; K is the powder factor, defined as the weight of explosive, in kg, per cubic meter of rock; Q is the mass, in kg, of the explosive in the hole; and RWS is the weight strength relative to ANFO (115 is the RWS of TNT).

The role of the Rosin Rammler equation is to estimate the complete fragmentation distribution. For a given mesh size or screen opening, X, this equation is able to estimate the percentage of fragments retained. It is given as[22]:

Equation 4

$$R_x = \exp^{-}\left(\frac{X}{X_c}\right)^n$$

where R_x is the proportion of fragments larger than the mesh size X (cm), and X_c is the characteristic fragment size (cm). The characteristic size is one through which 63.2% of the materials pass. If the characteristic size and the uniformity index are known, a size distribution curve can be plotted for the rock fragments[18]. The curve is plotted as percentage passing vs. mesh size. The former is obtained by subtracting R_x from one. Equation 4 can be rewritten to make direct use of the mean fragment size, X_{50}, as follows[20,21]:

Equation 5

$$R_x = \exp^{-0.693}\left(\frac{X}{X_{50}}\right)^n$$

From Equations 4 and 5, the characteristic size can be deduced as:

Equation 6

$$X_c = \frac{X_{50}}{0.693^{\frac{1}{n}}}$$

The third part of the Kuz-Ram model is the uniformity index, developed by Cunningham through several investigations which involved consideration of the effects of blast geometry, hole diameter, burden, spacing, hole length, and drilling accuracy[4]. This equation is given as[20,21]:

Equation 7

$$n = \left(2.2 - \frac{14B}{d}\right)\sqrt{\left(\frac{1+\frac{S}{B}}{2}\right)}\left(1-\frac{W}{B}\right)\left(abs\left(\frac{BCL-CCL}{L}\right)+0.1\right)^{0.1}\frac{L}{H}$$

where B is the burden (m); S is the spacing (m); d is the hole diameter (mm); W is the standard deviation of drilling precision (m); L is the charge length (m); BCL is the bottom charge length (m); CCL is the column charge length (m); and H is the bench height (m). Equation 7 is multiplied by 1.1 when using a staggered pattern. The value of n is essential in determining the shape of the size distribution curve, and is usually between 0.7 and 2. High values indicate uniform sizing, while low values indicate a wide range of sizes, including both oversize and fines[18,23]. Equations 3, 5, and 7 are what constitute the typical Kuz-Ram model.

Cunningham[2] makes modifications in the model twenty years on, mainly as a result of the introduction of electronic delay detonators. This leads to what is now known in the literature as the modified Kuz-Ram model. The adjustments by Cunningham incorporate the effects of inter-hole delay and timing scatter. The changes also incorporate correction factors for the rock factor and uniformity index. These changes lead to the modification of Equations 3 and 7 as follows[2]:

Equation 8

$$X_{50} = AA_TK^{-0.8}Q^{\frac{1}{6}}\left(\frac{115}{RWS}\right)^{\frac{19}{20}}C(A)$$

Equation 9

$$n = n_s\sqrt{\left(2-\frac{30B}{d}\right)}\sqrt{\left(\frac{1+\frac{S}{B}}{2}\right)}\left(1-\frac{W}{B}\right)\left(\frac{L}{H}\right)^{0.3}C(n)$$

where A_T is a timing factor for the effect of inter-hole delay, $C(A)$ is a correction factor for the rock factor, ns is the uniformity factor for the effect of timing scatter, and $C(n)$ is a correction factor for the uniformity index. Thus, the modified Kuz-Ram model comprises Equations 5, 8 and 9.

A major shortfall of the Kuz-Ram model is the underestimation of fines. Extensions to the model have, thus, emerged with the objective of improving the prediction of fines. The CZM and TCM are such models[18]. Kanchibotla, Valery, and Morrell[24] address the issue of fines via the CZM model, which provides fragment distribution based on the coarse and fine parts of the muck pile. The authors note that during blasting, two different mechanisms control rock fragmentation, ie tensile fracturing and compressive-shear fracturing. Tensile fracturing produces coarse fragments, while compressive fracturing produces the fines. The model predicts the coarser part of the size distribution using the Kuz-Ram model. The size distribution of the finer part is predicted by modifying the values of n and Xc in the Rosin-Rammler equation. Djordjevic[25] develops a two-component model (TCM) based on the same mechanisms of failure captured by Kanchibotla *et al*.[24] in their work. The model utilises experimentally determined parameters from small-scale blasting, and parameters of the Kuz-Ram model to obtain an improved prediction of fragment size distribution.

Ouchterlony[26] develops the KCO model which ties in the Kuz-Ram, CZM, and TCM models. The KCO model replaces the original Rosin-Rammler equation with the Swebrec function to predict rock fragment size distribution.

The replacement stems from the author's recognition that the Rosin-Rammler curve has limited ability to follow the various distributions from blasting. The Swebrec function proves to be more adaptable and is able to predict fines better. The model is given by Equations 10 and 11 as follows[26]:

Equation 10

$$P(x) = \frac{1}{[1 + f(x)]}$$

Equation 11

$$f(x) = \left[\frac{\ln\left(\frac{X_{max}}{X}\right)}{\ln\left(\frac{X_{max}}{X_{50}}\right)}\right]^{b}$$

where $P(x)$ is the percentage of fragments passing a given mesh size, X; X_{max} is the upper limit of fragment size; X_{50} is the mean fragment size; and b is the curve undulation parameter. Just like the Rosin-Rammler model, the Swebrec function has the mean fragment size (X_{50}) as its central parameter but introduces an upper limit to fragment size (X_{max}). While the aforementioned extensions to the Kuz-Ram model improve the distribution of fines, they introduce yet another factor into a predictive model that is already somewhat extended[2].

With the advancement in computational power, attention is being drawn to the use of machine learning (ML) in rock fragmentation prediction. Over the last decade, researchers have used multivariate regression (MVR) analysis, artificial neural network (ANN), and support vector regression (SVR) to predict fragment size distribution. In their work, Hudaverdi, Kulatilake, and Kuzu[27] use MVR analysis to develop prediction equations for the estimation of the mean particle size of muck piles. They develop two different equations based on rock stiffness. The equations incorporate blast design parameters (ie burden, spacing, bench height, stemming, and hole diameter) expressed as ratios, explosives parameters (ie powder factor), and rock mass properties (ie elastic modulus and in situ block size). Comparative analysis involving results of the prediction equations, Kuznetsov empirical equation, and the actual values prove the capability of the proposed models in offering satisfactory results. The authors make use of a diverse database (the largest ever used in research at the time) representing blasts conducted in different parts of the world. This makes their prediction models robust to a wide range of blast design parameters and rock conditions.

Building upon the work of Hudaverdi *et al*.[27], Kulatilake *et al*.[5] developed MVR and ANN models for the same set of data used in the former authors' work. The authors train a single hidden layer neural network model to predict the mean particle size for each of two groups of data, as distinguished by the rock stiffness. The authors perform extensive analysis to determine the optimum number of neurons for the hidden layer. Comparative analysis reveals that the MVR and ANN models perform better than the conventional Kuznetsov model. Shi *et al*.[9] build upon the work of Kulatilake *et al*.[5] by exploiting the potential of using support vector regression (SVR) for predicting rock fragmentation. Using the same data set as the previous authors, Shi *et al*.[9] develop an SVR model for predicting mean fragment size. They compare the results of the SVR model with those of ANN, MVR, Kuznetsov, and the actual values. The comparison shows that SVR is capable of providing acceptable prediction accuracy.

The effectiveness of prediction models is assessed via comparative analysis involving post-blast measurement. Post-blast measurement techniques have been developed over the years for determining the true fragment size after a blast was completed. An accurate predictive model will record insignificant deviation from the true fragment size. The available techniques for measuring fragmentation output can be classified as direct and indirect[3]. The direct methods include sieve analysis, boulder count, and direct measuring of fragments. The most accurate method of determining fragmentation is to sieve the whole muck pile. However, because muck piles are large, the use of sieving and the other direct methods can be tedious, time-consuming, and costly[5]. Thus, they are not practicable for muck pile fragment distribution. They can, however, be used for smaller amounts of fragment materials, and for very special purposes[3].

The indirect methods of fragment size measurement include digital image processing, and measurement of parameters, which can be correlated to the degree of fragmentation[3]. Digital image processing involves the use of sophisticated software and hardware for measuring fragment size. It is the latest fragmentation analysis tool and has largely replaced the conventional methods. The use of this tool comprises the following steps: image capturing of muck pile, image scaling, image filtering, image segmentation, binary image manipulation, measurement, and stereometric interpretation[5]. Though quick and cost-effective, this tool has some challenges. Non-uniform lighting, shadows, and a large range of fragment sizes can make fragment delineation very difficult. Another challenge is the overestimation of fines since the computer treats all undigitised voids between the fragments as fines. Thus, to obtain accurate estimation, a correction must be applied. Additionally, the wide variations in size may require different scales of calibration[5,28].

DATA AND METHODOLOGY

This section discusses the data and methods employed in this study. The data set comprises 102 blasts. Using this data set, we develop a multilayered artificial neural network and support vector regression models that satisfactorily predict mean rock fragment size.

Data Source and Description

The data set used in this work is obtained from the blast database compiled by Hudaverdi *et al*.[27], and subsequently used by Kulatilake *et al*.[5] and Shi *et al*.[9]. The compilation consists of blast data from various mines around the world. The data, therefore, represents a diverse range of blast design parameters and rock formations. Having such a diverse range of data is good for the purpose of this study, ie training machine learning models for prediction. The implication here is that the predictive ability of the ensuing models would span a wide variety of rock formations. The compilation by Hudaverdi *et al*.[27] represents one of the largest and most diverse blast data collections in the literature, and thus fits the purpose of this study.

Table 1 shows a sample of the data. A summary of the individual research projects from which Hudaverdi *et al*.[27] compiled the data is provided hereafter. Blasts with labels "Rc", "En", and "Ru" are from research by Hamdi,

Table 1: Sample blast data[5,9,27-33].

ID	S/B	H/B	B/D	T/B	Pf ($\frac{kg}{m^3}$)	X_b (m)	E (Gps)	X_{50} (m)
En1	1.24	1.33	27.27	0.78	0.48	0.58	60	0.37
En2	1.24	1.33	27.27	0.78	0.48	0.58	60	0.37
En3	1.24	1.33	27.27	0.78	0.48	0.58	60	0.33
Rc1	1.17	1.5	26.2	1.08	0.33	1.08	45	0.46
Rc2	1.17	1.5	26.2	1.12	0.3	0.68	45	0.48
Rc3	1.17	1.58	26.2	1.22	0.28	0.68	45	0.48
Mg1	1	2.67	27.27	0.89	0.75	0.68	50	0.23
Mg2	1	2.67	27.27	0.89	0.75	0.78	50	0.25
Mg3	1	2.4	30.3	0.8	0.61	1.02	50	0.27
Ru1	1.13	5	39.47	1.93	0.31	2	45	0.64
Ru2	1.2	6	32.89	3.67	0.3	2	45	0.54
Ru3	1.2	6	32.89	3.7	0.3	2	45	0.51
Mr1	1.2	6	32.89	0.8	0.49	1.67	32	0.17
Mr2	1.2	6	32.89	0.8	0.51	1.67	32	0.17
Mr3	1.2	6	32.89	0.8	0.49	1.67	32	0.13
Db1	1.25	3.5	20	1.75	0.73	1	9.57	0.44
Db2	1.25	5.1	20	1.75	0.7	1	9.57	0.76
Db3	1.38	3	20	1.75	0.62	1	9.57	0.35
Sm1	1.25	2.5	28.57	0.83	0.42	0.5	13.25	0.15
Sm2	1.25	2.5	28.57	0.83	0.42	0.5	13.25	0.19
Sm3	1.25	2.5	28.57	0.83	0.42	0.5	13.25	0.23
Ad1	1.2	4.4	28.09	1.2	0.58	0.77	16.9	0.15
Ad2	1.2	4.4	28.09	1.2	0.58	0.77	16.9	0.15
Ad3	1.2	4.4	28.09	1.2	0.58	0.77	16.9	0.15
Oz1	1	2.83	33.71	1	0.48	0.45	15	0.27
Oz2	1.2	2.4	28.09	1	0.53	0.86	15	0.14
Oz3	1.2	2.4	28.09	1	0.53	0.44	15	0.14

Du Mouza, and Fleurisson[29], and Aler, Du Mouza, and Arnould[30] at the Enusa and Reocin mines in Spain. The Enusa Mine is an open-pit uranium mine in a schistose with moderate to heavily folded formation. The Reocin Mine is an open pit and underground zinc mine. Blasts designated "Mg" are from a study by Hudaverdi[31] at the Murgul Copper Mine, an open-pit mine in northeastern Turkey. Those designated "Mr" are from a study by Ouchterlony *et al*.[28] at the Mrica Quarry in Indonesia. The rock formation is mainly andesite. Blasts with the "Sm" label are from an open-pit coal mine in Soma Basin, in Western Turkey[32]. Blasts labeled "Db" are from the Dongri-Buzurg open-pit manganese mine in Central India. The rock formation is generally micaceous schist and muscovite schist[33]. Blasts labeled "Ad" and "Oz" are, respectively, from the Akdaglar and Ozmert quarries of the Cendere basin in northern Istanbul. Rock formation at both quarries is sandstone[27].

The data set features blast design parameters that can be categorised as geometric, explosives, and rock parameters. The geometric parameters include burden, B (m), spacing, S (m), stemming, T (m), hole depth, H (m), and hole diameter, D (m). These are represented in the data set as ratios and include hole depth to burden (H/B), spacing to burden (S/B), burden to hole diameter (B/D), and stemming to burden (T/B) ratios. The powder factor, Pf ($\frac{kg}{m^3}$), represents the explosives parameter and shows the distribution of explosives in the rock. The elastic modulus, E (GPa), and the in situ block size, X_b (m), represent the rock parameters. Specifically, in situ block size represents the rock mass structure, while the elastic modulus represents the intact rock properties[27]. In effect, a total of seven rock fragment size prediction parameters are in the data set, and these will constitute the input parameters (independent variables) for the SVR and ANN models. The data set also features a post-blast parameter, ie X_{50}(m), which is the actual mean fragment size. This will be the output parameter (dependent variable) to be predicted by the models. **Table 2** shows the summary statistics of the seven input parameters and the mean fragment size for the entire data set.

Model Development

Support vector regression (SVR) and artificial neural network (ANN) models are built for a total of 102 blasts. We split the data into training and test sets comprising 90 and 12 blasts, respectively. The test set has Kuznetsov predictions matching the actual fragment size. This is for the purpose of comparative assessment of results. The data set is scaled within the range 0-1 since the parameters have different orders of magnitude. The scaling is performed using the MinMaxScaler function of the Scikit-learn Python library[34]. The SVR and ANN models are built using the Scikit-learn and Keras Python libraries, respectively[34,35].

Table 2: Summary statistics.

Variable		Minimum	Maximum	Mean	Standard Deviation
Input	S/B	1	1.75	1.20	0.11
	H/B	1.33	6.82	3.46	1.60
	B/D	17.98	39.47	27.23	4.91
	T/B	0.5	4.67	1.27	0.69
	Pf (kg/m^3)	0.22	1.26	0.55	0.24
	X_b (m)	0.29	2.35	1.16	0.48
	E (Gpa)	9.57	60	30.18	17.52
Output	X_{50} (m)	0.12	0.96	0.31	0.18

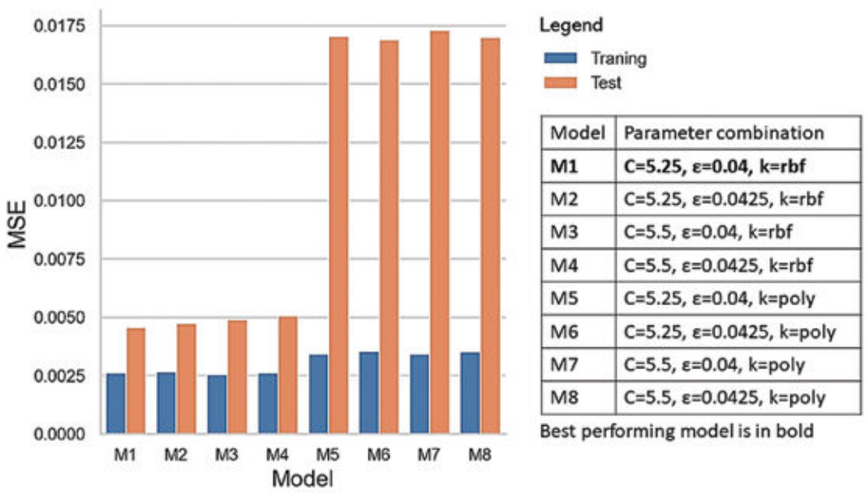
SVR Modeling

Using Scikit-learn, we develop and train a support vector regression model for prediction. The modeling process involves iterating over several combinations of the following support vector hyper-parameters: regularisation (C), epsilon (ε), and kernel (k). Four kernels are considered for modeling, ie radial basis function (rbf), polynomial (poly), sigmoid, and linear. Twenty-five different values of C are considered in the interval [1:10], and twenty-seven different values of ε are considered in the interval [1 10^{-6}:0.3]. This yields a total of 2700 combinations of hyper-parameters, each representing a unique SVR model. The process of searching for the optimal combination of these hyper-parameters (adjustable parameters which control the support vector) is known as hyper-parameter tuning. To aid with this process, the GridSearchCV function in Scikit-learn is used[34]. It involves building SVR models using each of these hyper-parameter combinations and subsequently using cross-validation to assess model performance. We adopt the five-fold cross-validation technique. This means that for each hyper-parameter combination, the data are split into five folds. The hyper-parameter combination undergoes five runs of model training, and during each run, a distinct fold (one-fifth of the training data) is set aside for validation purposes. The final score assigned to the hyper-parameter combination is the average validation score from the five runs. This process is repeated for all other hyper-parameter combinations. We retrieve the best performing combination of hyperparameters, and these are C = 5.25, ε = 0.04, and kernel = rbf. The final SVR model is thus built using these hyper-parameters.

In this study, retrieval of the best performing combination is based on the mean squared error (MSE) scoring metric. The MSE is a statistical metric that provides a means of assessing performance between two or more models. For each model, the MSE measures the average squared difference between the actual and predicted values. A perfect model would yield an MSE of zero, signifying that the actual values are perfectly predicted by the model, ie there is no error in prediction. In machine learning, the best-performing model among alternatives will be the one with MSE closest to zero. We show the MSE values for selected hyper-parameter combinations for the training and test data in **Figure 3**. From the figure, we observe that models with rbf kernels have better generalisation abilities in respect of unseen, real-world data, ie data not included in the training process. This is represented by the test data. The best-performing model retrieved from the hyper-parameter tuning is of the rbf kernel type. It yields the lowest MSE value for the test data.

ANN Modeling

Using Keras, we develop a variety of multilayered ANNs with up to four hidden layers for prediction. In each instance, hyper-parameter tuning is performed to obtain an optimal number of neurons (units) for the hidden layers under consideration. In all cases, the input and output layers have fixed neurons, being seven and one, respectively. These represent the seven input parameters, and the output parameter (X_{50}), which we seek to predict. **Figure 4** is a schematic representing the general architecture of the ANNs used in this study.



Model	Parameter combination
M1	**C=5.25, ε=0.04, k=rbf**
M2	C=5.25, ε=0.0425, k=rbf
M3	C=5.5, ε=0.04, k=rbf
M4	C=5.5, ε=0.0425, k=rbf
M5	C=5.25, ε=0.04, k=poly
M6	C=5.25, ε=0.0425, k=poly
M7	C=5.5, ε=0.04, k=poly
M8	C=5.5, ε=0.0425, k=poly

Best performing model is in bold

Figure 3: MSE plot for selected SVR hyper-parameter combinations.

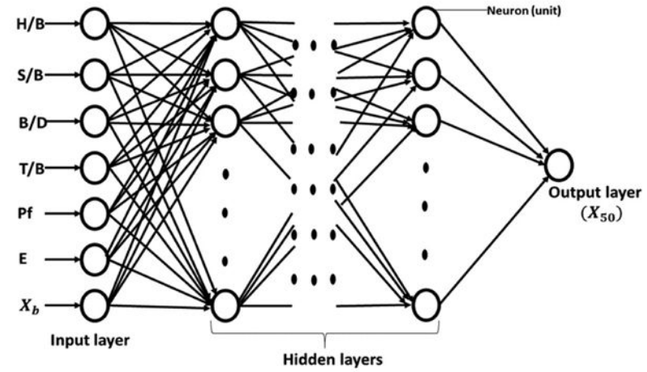


Figure 4: ANN architecture for rock fragmentation prediction.

For each instance of hidden layers, hyper-parameter tuning is performed using the Bayesian optimisation object in Keras[35]. The process involves iterating over several combinations of neurons for a given instance of hidden layers and returning the combination that yields the best performance. This process can be very cumbersome and time-consuming when carried out manually. The use of Bayesian optimisation saves time by automating the search process for the best combination of neurons for a given number of hidden layers. During the search process, 20% of the training data is set aside for validation purposes using the MSE scoring metric. The remaining data are used for training, and this involves running 1500 epochs to yield an acceptable reduction in prediction error.

Table 3 shows the results for the various hidden layers considered. For each instance of hidden layers, the table shows the optimal number of neurons returned via hyperparameter tuning. The neural network with four hidden layers is selected as the final ANN model. This is based on the test scores, which represent the ability of the models to generalise to unseen, real-world data. The four-hidden-layer architecture has the lowest test score.

In the second configuration of hidden layers, the batch normalisation (BN) technique serves to control model overfitting, so as to improve model generalisation in respect of unseen, real-world data. Batch normalisation applies a transformation that maintains the mean output close to zero and the output standard deviation close to 1, thereby standardising the inputs to a given layer[35]. We show the performance of selected hyper-parameter combinations for the various hidden layer instances in **Figure 5**. The figure shows how the final ANN model (M8) compares with other models from the hyper-parameter tuning exercise. Model M5 has the worst generalisation performance while model M8 has the best generalisation performance.

RESULTS AND DISCUSSION

Through hyper-parameter tuning, we obtain the final SVR and ANN models. For the purpose of assessing model generalisation, we subject these models to testing. The test data set comprises 12 blasts; these are not used for training. The performance of the model on this data shows how well it will perform when deployed in the real world. **Table 4** shows the performance of the final models on the training and test sets using the mean squared error (MSE) as a scoring metric.

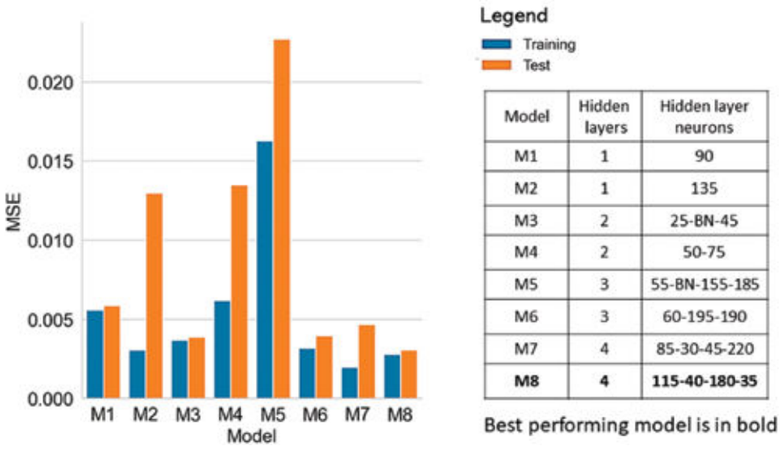
For the purpose of comparative assessment, the Kuznetsov empirical technique, ie Equation 3, is used to predict the mean rock fragment size for the test data. Test results obtained for the ANN and SVR models are compared with those for the Kuznetsov technique and the actual values. **Table 5** and **Figure 6** show the results for all three modeling techniques. It is observed that the ANN model records the least error while the Kuznetsov records the highest error. The coefficient of determination (r^2) measures the proportion of the variation in the dependent variable (mean fragment size) that is accounted for by its relationship with the independent variables. It ranges between zero and one. A model with r^2 closer to one is said to be reliable in predicting the dependent variable. The foregoing indicates that the ANN and SVR models are better able to model the relationship between the dependent and independent variables than the Kuznetsov empirical model. They show superior performance to the Kuznetsov as a result of their inherent ability to model complex, nonlinear relationships, such as exist between rock fragment size and blast design parameters.

Table 3: Optimal neurons for hidden layers.

Number of hidden layers	Optimal Neurons for hidden layers	MSE for test data	Selected model
1	90	0.0059	
2	25-BN-45	0.0039	
3	60-195-190	0.0040	
4	115-40-180-35	0.0031	✓

Table 4: Model performance.

Model	Mean Squared Error (MSE)	
	Training	Test
1	90	0.0059
2	25-BN-45	0.0039
3	60-195-190	0.0040
4	115-40-180-35	0.0031



Model	Hidden layers	Hidden layer neurons
M1	1	90
M2	1	135
M3	2	25-BN-45
M4	2	50-75
M5	3	55-BN-155-185
M6	3	60-195-190
M7	4	85-30-45-220
M8	**4**	**115-40-180-35**

Best performing model is in bold

Figure 5: MSE plot for selected ANN hyper-parameter combinations.

Table 5: Results for test data.

Blast number	Mean fragment size (m)			
	Actual	Preuctions		
		ANN	SVR	Kuznydov
1	0.47	0.44	0.38	0.48
2	0.64	0.68	0.64	0.71
3	0.44	0.38	0.41	0.42
4	0.25	0.25	0.25	0.33
5	0.20	0.15	0.14	0.27
6	0.35	0.21	0.52	0.09
7	0.18	0.19	0.19	0.38
8	0.23	0.17	0.18	0.22
9	0.17	0.17	0.19	0.25
10	0.21	0.21	0.20	0.12
11	0.20	0.21	0.19	0.13
12	0.17	0.24	0.26	0.23
Coefficient of determination (r^2)		0.87	0.81	0.58

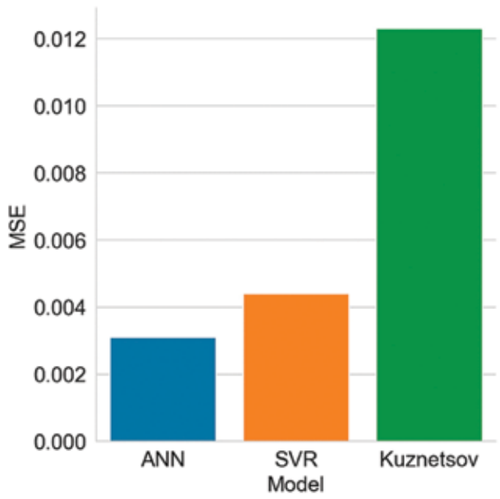


Figure 6: MSE plot for test data.

CONCLUSIONS AND FUTURE WORK

The paper successfully demonstrates the potential of achieving higher accuracy in mean rock fragment size prediction using multilayered artificial neural network (ANN) and support vector regression (SVR). Using varied blast data sets from different parts of the world, we obtain training and test sets comprising 90 and 12 blasts, respectively, for building multilayered ANN and SVR models. Both models perform satisfactorily and better than the conventional Kuznetsov empirical model. The paper further demonstrates the possibility to analyse a varied number of hidden layers for a neural network in a less cumbersome way using Keras. Keras makes it less time-consuming to consider the performance of a wide variety of hidden layers and neurons via the Bayesian optimisation feature. Thus, multilayered ANN analysis of rock fragmentation, which is typically timeconsuming, can be carried out in a relatively shorter time. The end goal here is that blasting engineers would be able to fully exploit the potential of the multilayered ANN architecture for improved performance without having to do manual hyper-parameter tuning. The trained ANN and SVR models could be incorporated into existing fragmentation analysis software to give blasting engineers more accurate options for mean rock fragment size estimation. This incorporation would make it possible for blasting engineers to have access to results from both empirical and machine learning techniques. Blasting engineers would then be able to conduct post-blast analysis to verify the improved accuracy offered by the machine learning techniques. Commercial fragmentation software providers could adopt this integrated approach to gradually build client confidence in the use of machine learning techniques with time.

In the future, we seek to improve model performance via data augmentation. We intend to do this using the variational autoencoding (VAE) technique. VAE is a deep learning technique that fits a probability distribution to a given data set, and then samples from the distribution to create new unseen samples. Thus, the VAE offers a means of augmenting the data set used in this study to improve model training, and thus enhance pattern recognition and prediction. We also seek to build additional rock fragmentation models using other machine learning techniques. The final phase of this project will involve developing robust machine learning-based fragmentation software that will not only predict the mean fragment size but the entire fragment size distribution.

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Weening the industry away from diesel

Off-Highway trucks, Off-Road trucks, Mining trucks, Haul trucks, whatever one calls them, they are now larger than ever and getting bigger with every generation and stronger to handle the harshest working conditions across the world, this indeed represents major challenges for companies to reduce emissions in their fleets with some weighing as much as 500 tons, their electrification will have by far the largest impact on reducing emissions in the industry's fleets.

Mining giants BHP, Rio Tinto, and Vale launched a recently well documented through the trade media a challenge to companies to accelerate the electrification of the surface mining industry to slash emissions, but also make industry safer and more productive.

There are an estimated 50,000 off-road haul trucks that weigh over 90 metric tons in operation around the world according to a report by Parker Bay Mining, and an additional 68,000 that are inactive. Parker Bay is a leading USA specialist company providing data, analysis, and related market intelligence services for the mining equipment industry.

CHALLENGES

But with large trucks come large challenges 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 (i.e., while it is being loaded or it is dumping). This would of course require miners to purchase many more trucks that would make it difficult to do so economically at large scale as mine electrification requires considerable integration between mine planning and operations. What is needed is to develop new charging solutions that can be incorporated into operations in parallel to the development of battery trucks, to ensure the creation of a truly sustainable electric haulage system in all aspects – clean, competitive, and flexible.

Electric-powered equipment is also a trend, although the sheer size of much of the equipment in quarrying and mining poses certain logistical issues.

The machines in this market are too large to be battery powered at the moment. There has been a shift away from diesel power to natural gas, but also electric power. There is other [equipment] that are electric drive, sometimes powered by onboard diesel, but there are other options for those type of electric drive equipment, such as hydraulic excavators that can be electric.

One of the issues with transitioning to that is you need to have access to large power, either generation onsite or direct to site. And that is a limiting factor for some mining operations. There is a lot of investment in actually getting to the point where all of your haul routes and such can be utilising that type of technology.

Moving away from diesel power to so called environmentally friendly equipment in terms of emissions and other things, such as electric, is somewhat more difficult to implement in certain instances across the mining markets.

With autonomous, remote controlled and electric equipment – to varying degrees – becoming increasingly common place in mining and quarrying equipment fleets, it is clear that in the future the machines operating in this sector will be expected to be more than simply tough and robust.

One solution proposed is adapting trolley assist systems which are currently used to propel diesel-electric trucks to power battery-electric trucks during their day-to-day operations. But current systems have certain drawbacks

ESG REQUIREMENTS- IS THIS THE END FOR DIESEL?

Whilst a lot of the mining majors are announcing their ESG requirements one has to say that not all mining companies have the financial clout to implement measures that would replace the use of existing diesel machines, there are an awful lot of machines out there that are coming to the end of their life cycle, add to that the impact of Covid and the Russian/Ukraine situation many operations are not in a position to purchase new equipment.

The path to net-zero carbon emissions is a global, multi-sector challenge and developing road maps to achieving that goal requires industry commitment, innovation, and new technological solutions. The challenges to achieving decarbonisation road maps in the mining industry need to be tailored by operation, addressing the key pillars of decarbonisation: energy efficiency, hybrid power, microgrid integration, alternative vehicles, mine design, and process adaptation to alternative energy sources. Specifically, one of the critical challenges that needs to be addressed is the reliance on diesel fuel.

To comply with ESG requirements and expectations, mining companies are developing decarbonisation strategies that require scenario modelling and a review of available funding, technology, and assets. In October last year Anglo-Australian miner Rio Tinto announced its plans to reduce carbon emissions by 50% by 2030, more than tripling its previous target. Rio is planning to replace diesel trucks with battery technologies or hydrogen. The miner is also working towards full electrification of autonomous trains that run on its 1,700-kilometre rail network. To find the best solutions to reach its goal, Rio is partnering with suppliers, governments, and customers. Rio also aims to reduce shipping emissions by 40% by 2030 and will require the shippers of its products and suppliers of goods and services to achieve net zero by 2050.

Australian iron ore billionaire Andrew Forrest has recently unveiled plans to build a green energy production centre and initially, the focus will be on hydrogen electrolysers, followed by wind turbine equipment, solar photovoltaic (PV) cells, and electrical cabling. Forrest has declared that he wants to build more than 100GW of renewable hydrogen capacity by 2030. The green energy is initially set to power mining operations in Queensland. As part of his sustainability push, Forrest is also investing in a grid-connected battery system and a green mining fleet powered by hydrogen and battery electric energy solutions.

Also in Australia, mining company Oz Minerals wants its next mining project, West Musgrave, to be carbon neutral. The plan is to power the copper-nickel project completely via a renewable on-site power plant. The mining fleet is also set to be emission free. The goal is to create a zero-emissions value chain producing mining goods that can be marketed as clean, green products for consumers.

MINING FLEET

The mining fleet is one of the industry's primary sources of on-site greenhouse gas (GHG) emissions. Mobile mining equipment at a surface mine can account for up to 30% of on-site GHG emissions – or up to 80 percent if the mine doesn't have contiguous smelting or refinery facilities. Large mining haul trucks can represent more than 50% of the total surface mobile fleet's GHG emissions.

In 2018, the International Council on Mining & Metals (ICMM) launched the Innovation for Cleaner Safer Vehicles (ICSV) initiative, which brings together twenty-seven of the world's leading mining companies and nineteen original equipment manufacturers to accelerate innovation in the development of a new generation of mining vehicles and to improve existing vehicles. ICMM's goals are to reduce GHG emissions, emissions of diesel particulate matter, and vehicle interactions for improved safety. The ICSV initiative aims to achieve GHG-free surface mining vehicles by 2040, tackling the main source of Scope 1 emissions, which are direct emissions from owned or controlled sources (i.e., emissions from the surface mining fleet).

HYDROGEN POWER

Anglo American this year has unveiled the world's biggest hydrogen-powered mine haul truck. The massive truck is three stories tall and weighs in at over 220-tonnes. The truck is said to have entered operations at Mogalakwena PGMs mine in South Africa.

The truck had undergone building, modification and testing in the US for just over 12 months, before being transported to South Africa. It was first motion tested at Mogalakwena under real mining conditions in March this year.

The nuGen prototype is said to be the first of a large fleet, said to replace the company's conventional diesel-powered trucks. The hydrogen truck is powered by a 1.2 MWh battery pack, with eight fuel cells producing a total output of 2,682 BHP. The hydrogen truck is also said to boast of multiple electric motors, regenerative braking, and the ability to carry 290 tonnes of ore.

The NuGen hydrogen-powered truck carries 68 kg of hydrogen on board, which is sufficient to operate the truck for one to two shifts, depending on the load.

Refuelling takes place at a hydrogen "pump" for about nine minutes before the truck gets back to work. The company currently has plans to retrofit 40 diesel-powered trucks to hydrogen at their mine in South Africa. Thereafter, the company also has plans to roll out the hydrogen tech to power their global fleet consisting of around 400 trucks.

Duncan Wanblad, CEO, Anglo American, said that if the pilot operation of the hydrogen truck is successful and implemented across the globe, it would help remove 80% of the diesel emission at the open-pit mines. By replacing these with the hydrogen truck, it could keep '700 cars' worth of carbon dioxide emissions out of the atmosphere. Diesel emissions from Anglo's haul truck fleet accounts for between 10% and 15% of its total Scope 1 emissions and a fleet overhaul is, therefore, an important step in the

group's pathway to carbon-neutral operations by 2040. The company aims to convert between 10 and 20 trucks a year globally, taking three to four years to complete the full fleet transition.

WHEN MICROGRIDS MAKE SENSE FOR MINES

On-site power for remote mining operations can be more cost-effective than electricity from a faraway grid connection point because they meet the sweet spot requirements. Remote mining operations' loads tend to be less than 20 MW.

Diesel generators in the past have been a main choice for mines because of their low cost:

However, renewable energy alternatives like solar-plus-storage systems are becoming an increasingly competitive option to displace diesel and decarbonise off-grid mines

Mining is an important focus because of its energy intensity. As of 2020, the mining sector accounted for about 38% of global industrial energy use and energy-related expenses in mines represented about 30% of the total operating costs.

Some clean energy companies have begun offering on-site systems to address the need for clean power in mining efforts.

For example, a Hitachi ABB microgrid system is greening mining operations and providing continuous power for off-grid mining operations at Indo Tambangraya Megah's facility in Bontang, East Kalimantan in Indonesia.

CONCLUSION

All in all, mining is a dynamic sector facing issues like difficult operating conditions, constraints around energy availability, and potential impact of volatile fossil fuel prices – all of which creates an opportunity for decentralised power production. The transition from fossil fuels to renewable energies as power sources in the heavy industries is one of the main climate change mitigation strategies. The carbon footprint in mining is related to its inherent extraction process, its high demand of electric power and water, and the use of diesel. However, considering its particular power requirements, the integration of microgrids throughout the whole control hierarchy of mining industry is indeed an emergent topic

Green energy technologies enable mining and quarrying operations small and large the opportunity to lower their carbon footprints by creating more effective ways to generate electricity for use in their respective mines. There are many alternate solutions not discussed in this article that would suit some operations and not others. Many small-scale mining operations will be reluctant to ween themselves away from diesel due to absence of any substantial investment or aid from their respective governments. Mining companies that can afford to power their operations with renewable energy, operate electric or hydrogen-powered truck fleets and integrate recycling in their value chains will be best placed to sell low-carbon premium minerals.

Managing conveyor belt carryback

"Carryback" is defined as the material that fails to unload from a conveyor belt, adhering to the belt and typically falling off at some point other than the intended discharge, and it's one of the main sources of fugitive materials, estimated to account for 85% of all conveyor maintenance issues. Accumulation on moving components from dirty belts can cause premature wear and require frequent cleanup, which exposes workers to potential workplace injuries and respiratory diseases.

It can be shown practically and theoretically that a conveyor belt cannot be cleaned 100%, because the surface of the belt and the blades are not without imperfections. However, this doesn't mean operators shouldn't take a proactive approach to keeping the belt clean. Most industries have gravitated to basic mechanical scraping with a metal or elastomeric blade for flat rubber or PVC belting as the best combination of effectiveness, ease of maintenance and low belt wear to yield the lowest cost of ownership.

BELT CLEANERS

Belt cleaning effectiveness varies day to day with changing conditions and the number and type of cleaners applied, as well as the maintenance they receive. Keeping the material in the process is always better than letting it accumulate on components and build up under the conveyor. Without effective belt cleaning, experience has shown that as much as 3% of the total cargo can be lost due to spillage, dust and carryback.

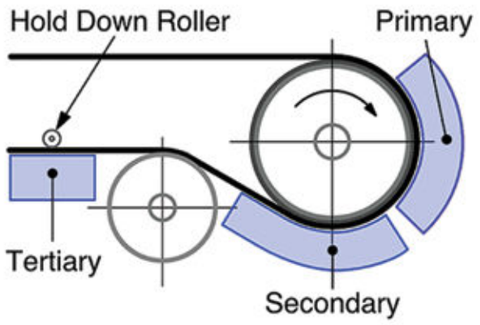
The exposure to hazards and injuries is also reduced when less cleanup is required, saving significant – but seldom considered – indirect costs. The key to consistent cleaning effectiveness is to control the process through proper selection, installation, inspection and maintenance of the belt cleaning system and establish a safe cleanup routine and schedule.

The use of multiple mechanical scrapers on a belt has been accepted for quite some time as an effective cleaning approach. In most operations, multiple cleaners are required to reduce the carryback to a safe, acceptable level while limiting manual cleanup to weekly or even monthly tasks.

EFFECTIVENESS VS. EFFICIENCY

The undulating action of the loaded belt passing over idlers tends to cause fines and moisture to migrate and compact on the surface of the belt. The amount of carryback that clings to the belt can range from a few grams to a few kilograms per square meter. The level of belt cleaning required is a function of the operational schedule and method of collecting / disposing of the carryback that is cleaned from the belt or dislodged by return idlers and collects outside of the conveyor discharge chute.

When discussing the efficiency of a belt cleaner, it's meaningless to talk about efficiency without stating the initial level of carryback. When considering the



Belt cleaning positions.

Typical installation of primary, secondary and tertiary cleaners.

beginning and ending levels of carryback as a measure of improvement, effectiveness is a better term. Some guidelines do exist. The U.S. Bureau of Mines states that an average of 100 g/m2 of carryback is a reasonable level of performance for belt cleaning. At this level, a 1200 mm (48-inch) wide belt traveling 2 m/s and operating 24/7 would create a cleanup workload of about 7 tons per day, a significant labor investment that also increases worker exposure to a moving conveyor and the associated risks.

Carryback level determines the cleanup schedule, but in reality, a typical belt cleaner loses effectiveness over time due to wear, lack of inspection and maintenance. On systems with average or poor maintenance, effectiveness values are generally in the range of 40-60%, thus the need for multiple cleaners.

CLEANING LOCATION

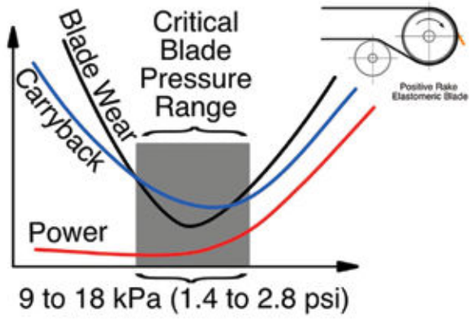
Unfortunately, designers often focus on the lowest installed cost of the structure around the head and snub pulleys, without allowing enough space for optimum cleaner installation. The figure below shows the clear areas needed on a discharge chute for installation of belt cleaners in the optimum positions. The installations should be at an ergonomic height above the work platform to encourage proper inspection and service. Consideration in the design stage for locating cleaners in the optimum locations will lead to more effective inspections, maintenance and belt cleaner performance.

Belt cleaners can be placed anywhere along the return run of the belt, as long as the belt is supported in some fashion. Since it's desirable for the carryback cleaned from the belt to be returned to the main material flow, most belt cleaners are installed inside the discharge chute. Cleaning on the head pulley – labeled the 'primary cleaning position' – is preferred. Cleaning the dirty side of the belt before it reaches a snub, bend pulley or return idlers is considered less desirable, requiring a dribble chute for cleaners in the secondary position.

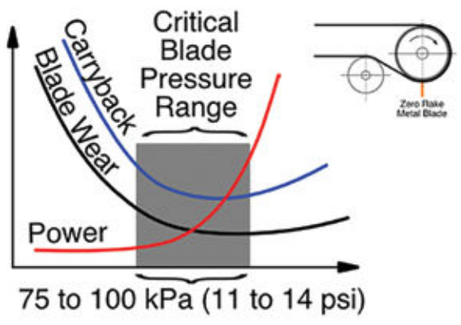
The secondary position is complicated by another fact: the nature of carryback is such that it can adhere to vertical surfaces and not flow down a sloped dribble chute. A tertiary position is sometimes required for difficult materials or critical applications such as conveying over wetlands. In such cases, the tertiary cleaners are often enclosed in a spray box and the effluent directed to a settling basin.

BELT CLEANING PRESSURE & BLADE WEAR

Without enough cleaning pressure, the blade cannot stay in contact with the belt, resulting in poor carryback removal effectiveness and increased blade and belt wear. With too much cleaning pressure, the cleaning performance declines due to deflection of the elastomeric blade or metal blade indentation into the rubber belt. Power consumption also increases dramatically with excessive cleaning pressure.



Elastomeric primary blade pressure at a positive rake angle.



Metal secondary blade pressure at zero rake angle.

Keeping a belt cleaner properly tensioned is critical for maximum effectiveness and lowest cost of ownership. The cleaning pressure usually varies over time, based on the maintenance department's attention or lack thereof. Some manufacturers have begun to offer automatic tensioners and wear indicators which maintain the optimum cleaning pressure and alert operators when blades are worn.

FINAL THOUGHTS

Many belt cleaner systems are installed and forgotten. A survey of technicians indicated that about 25% of all belts have cleaners installed, and of that percentage only about 25% are properly maintained. Lack of inspection and maintenance results in a gradually lower level of effectiveness, higher operating cost and an increased exposure to the hazards associated with cleaning up carryback.

Effective belt cleaning starts in the design stage, with adequate space for cleaners and well-positioned work platforms for ergonomic inspection and maintenance access. Service-friendly designs improve production, minimising carryback and prolonging the life of equipment.

Automatic tensioner maintains optimum cleaning pressure without operator intervention.

If the cleaners are located in the optimum positions and easy to access, it is more likely that regular inspection, cleaning and maintenance will be performed, delivering optimum results.

New atomised mist cannon manages dust in unfavorable weather conditions

The design features three remote-controlled stage and precision oscillation for optimum coverage.

The next advancement in industrial dust suppression has been introduced by the leader in atomised mist technology, a powerful cannon that is designed to fight dust with maximum efficiency. Developed in response to the needs of customers in areas with variable winds, the DustBoss® DB-60 Surge® features water propelled at high velocity from a center nozzle, combined with the industry-proven fan and misting ring system. With three remote-controlled stages and precision oscillation for optimum command over water volume and coverage area, the cannon uses high-powered jets that surge through the wind for over 250 feet (76.2 m) to suppress both surface and airborne dust. The result is effective and versatile dust mitigation in challenging weather for outdoor operations ranging from demolition to bulk material processing and storage.

“Our customers operate in very different circumstances; some with high-reach excavators, some in open areas without natural barriers, while others are located in narrow corridors where wind velocity is amplified,” explained BossTek Dust Control Specialist Mike Lewis. “What these customers have in common is the difficulty in controlling fine atomised mist during blustery conditions. So we worked with our industry partners, listened to their feedback and engineered our most versatile and innovative machine to date.”

Lewis recalled that one of the initial drivers behind the new design was a need in the demolition industry. “Several customers described their challenges in suppressing dust during demolition of high-rise structures,” he said. “Some of them use attachments that can be mounted on a high-lift boom, but that can bring its own complications. When we started working on a solution, we realised that this technology would also deliver benefits to a wide range of applications in which variable wind conditions can be a problem, such as port facilities, material processing operations and large outdoor storage facilities.”

The DB-60 Surge combines the power of an industrial fan, misting ring and heavy-duty barrel with the reach and force of a central high-pressure spray nozzle. The pressurised spray resists wind shear and even uses the force of the wind to further fragment and carry the droplets, enhancing its dust suppression capabilities. This is achieved without the need for the high water output associated with a hydrant-dependent hose or industrial sprinkler system.

In high-wind situations, dust is lifted into the atmosphere and carried beyond the site line over long distances, which can lead to permit violations. Operators of bulk storage mounds, demolition sites, ports, recycling material piles, etc. often mitigate particulate emissions using a sprinkler or hose to saturate a material’s surface. The higher the wind, the more water pressure is required to break through the shear, resulting in greater amounts of water filling the surrounding work area -- often 300 GPM (1135 lpm) or more.

There are several issues associated with the use of hoses and industrial sprinklers. Hoses typically require manual labor, removing workers from other critical tasks. Moreover, both sprinklers and hand-held hoses contribute to high water bills. Taking compliance and expenses into consideration, the long-term cost of operation for sprinklers and hoses is higher than it might appear.

The DB-60 Surge addresses wind, labor and water usage issues. While striving to stay compliant with dust regulations, operators can now better match the water requirements to the specific application. Fed by a standard 1-½ in. (38 mm) hose with a cam-and-groove quick disconnect coupling, the powerful booster pump delivers as much as 500 PSI (27.5 BAR) of water pressure to the center nozzle, with an output of 37-100 GPM (140-378 lpm).

Controlled by a 3-stage system adjusted by a hand-held remote, the first stage is highly effective on moderate days for airborne and surface coverage. It uses the powerful 25 HP / 30,000 CFM (849.5 CMM) fan and misting ring to deliver millions of fine atomised mist droplets over a wide area, which collide with tiny dust particles and drag them to the ground. For windy days, stage two features a pressurised stream delivered by the central nozzle. On high wind days, operators can utilise the fan, misting ring and center nozzle for maximum coverage.

DB-60 SURGE WATER USAGE

OPERATING LEVEL	FLOW RATE @ 50 PSI	3.45 BAR
STAGE 1: OUTER SPRAY RING	30 GPM	114 LPM
STAGE 2: CENTER NOZZLE	70 - 100 GPM	265 - 378 LPM
STAGE 3: OUTER RING & CENTER NOZZLE	100 - 130 GPM	378 - 492 LPM

Figure 1: Water volume of each stage.

The versatility and coverage area is extended with the customisable 359º horizontal oscillation range and 0º-50º vertical throw angle. Using the hand-held remote, the operator can raise the spray angle to reach extended heights, directing the 250 foot (76 m) spray to areas such as high-reach demolition or across the beam of large bulk cargo ships. The oscillation range is easily controlled with the left and right trigger of the remote control to customise the precise desired horizontal range.

Mounted on a heavy-duty roadworthy trailer for towing at highway speeds with a standard ball hitch, it can be placed by a pickup truck, skid steer or lift truck wherever dust suppression is needed. As supplied, the DB-60

The design features three remote-controlled stage and precision oscillation for optimum coverage.

Surge can run potable or non-potable water, as it is equipped with two in-line 30 mesh, 595 micron filters to avoid clogging. One filter is located at the water entry point to the booster pump, another prior to the pipe feeding the central nozzle.

After the initial setup, the DB-60 Surge requires no labor to operate. The remote control has a 1000 foot (305 m) range, so operators using heavy machinery from high-reach excavators to front loaders can command the machine without leaving the cab.

Lewis mentioned that other options are already available, including tower mounting and a version of the company’s popular Fusion lineup, which pairs the Surge with a generator to alleviate the need for a nearby power source.

“DustBoss is known for its rugged quality and long equipment life, often described as one of the most reliable and low-maintenance pieces of equipment on any job site,” he added. “Our 3-year or 3000-hour warranty is evidence of our confidence in the products. The DB-60 Surge is designed with that same philosophy and is built to last.”

The DB-60 Surge is built for versatility and continuous use in punishing outdoor weather conditions.

Epiroc pioneer in reverse circulation drilling

Epiroc's new Explorac RC30 Smart automation-focused reverse circulation drilling machine boasts increased capabilities in productivity and safety features.

With the latest RCS architecture, advanced hands-free functionality and increased pullback capacity, the Explorac RC30 Smart ensures unparalleled operator safety through the entire drilling process while maximising productivity.

It provides 30 tonnes of pullback capacity to deliver the metres of drill depth necessary to satisfy the contractual demands of drillers today.

The automated rod hand ling system offers the capability for a single operator to seamlessly add and remove rods from the drill string from the surface all the way to target depth.

Numerous smart features, including feed beam centralisers with variable grip force and an advanced breakout system with automatic application of thread grease, help maximise the life of drilling consumables and dramatically increase operator safety.

Epiroc surface division global product manager Cole Carpenter said the company had listened to the market and pushed to reach the high level of automation which drilling companies require.

"Today, both big and small operations must meet a high safety level – and automation simply removes personnel from dangerous environments," he said.

"Explorac RC30 Smart improves productivity and safety in exploration drilling operations, being highly automated, reliable and ready for the future.

"We have made improvements in both functionality, automation and safety – continuing our focus on being an industry leader in the development of sustainable reverse circulation drilling products."

The Explorac RC30 Smart architecture also has been designed for long-term scaling of rig features and functionality. As a result, the machine configuration can be tailored for the application while maximising customers' return of investment throughout the life of the machine.

"Ultimately, we have made the investment at Epiroc to ensure that Explorac RC30 Smart provides maximum efficiency for drillers in the field today, and we will continue that focus in providing long term solutions for generations to come," Carpenter said.

Explorac RC30 Smart will be available for orders in Australia later this year.

Britain to increase tariffs on Russian platinum and palladium

Britain announced recently it will increase tariffs on platinum and palladium imports from Russia and Belarus in a new package of sanctions targeting £1.7-billion ($2.10-billion) of trade, which it said aimed to further weaken Russian President Vladimir Putin's war machine.

Import tariffs on a range of products will be raised by 35 percentage points, Britain said, while it will also ban exports of goods such as chemicals, plastics, rubber and machinery to Russia, worth a combined £250-million ($310-million).

The UK government will legislate for the new sanctions in due course, it said.

Britain is acting in concert with its Western allies to try to cripple the Russian economy as punishment for Russia's invasion of Ukraine, and it has already sanctioned more than 1,000 individuals and businesses.

Russia, a leading producer of platinum and palladium, has called the invasion it launched in February a "special military operation" aimed at demilitarising and "denazifying" its neighbour.

British Finance Minister Rishi Sunak said more than £4-billion of goods would be subject to import and export sanctions, doing "significant damage to Putin's war effort". They mark a third wave of sanctions against Russia since the invasion of Ukraine.

"Working closely with our allies we can and will thwart Putin's ambitions," Sunak said in a statement.

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