Volume 18 | Issue 1 | February 2021

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Volume 18 • Number 1 • February 2021

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All subscriptions payable in advance.
Published 6 times per year, post free:
UK: £60.00 **Worldwide:** £70.00 | ISSN No: 2045-2578 | D-U-N-S No: 23-825-4721

Weir wins £95m aftermarket order to support Iron Bridge magnetite Project in Australia

The Weir Group, a leading provider of premium mining technololgy, has won a £95m order to provide aftermarket components and service to the Iron Bridge magnetite Project in Western Australia.

The aftermarket contract follows Weir's success in winning a record £100m order for original equipment for the Iron Bridge project in 2019, including its innovative Enduron® High Pressure Grinding Rolls (HPGRs) that enable dry processing of ore and use at least 30% less energy than traditional alternatives.

The Iron Bridge magnetite Project is a US$2.6bn joint venture between Fortescue Metals Group's subsidiary FMG Magnetite Pty Ltd and Formosa Steel IB Pty Ltd and is located in the Pilbara region, around 145 kilometres south of Port Hedland.

Both the aftermarket order and revenues will be recognised over the seven year period of the agreement which starts in 2022, in line with the Project's initial production.

Ricardo Garib, President of Weir Minerals said:

"This is another landmark order for Weir. Having helped design an energy and water efficient magnetite processing plant, we are delighted to provide operational support for Iron Bridge from 2022. It is an excellent example of the value that Weir's innovative engineering and close customer support can create for all our stakeholders and reflects the key role we have to play in making mining operations more sustainable and efficient."

Weir's Enduron® HPGRs are increasingly replacing conventional mills in comminution (crushing, screening and grinding) circuits. In addition to their energy and water savings they also reduce grinding media consumption, while their wearable components last longer, reducing maintenance costs. Additionally, HPGRs contribute significantly to carbon dioxide emission savings.

Stuart Hayton, Managing Director of Weir Minerals Netherlands, where the Enduron® HPGRs are designed and manufactured commented:

"This is an important project for Weir and for the broader mining industry. We know comminution is one of the most energy intensive parts of the mineral process and with our Enduron® HPGRs we have a unique ability to offer significant cost, energy and water savings to customers around the world. As the mining industry evolves we are commited to continuing to innovate, reducing miners' costs and environmental impact."

This latest contract award means Weir now has more than £200m of orders from the Iron Bridge Project including its Enduron® HPGRs, GEHO® and Warman® pumps, Cavex® Hydrcyclones and Isogate® valves.

To support the Project and future growth, Weir will build a new service centre in Port Hedland, Western Australia, thereby providing employment and training opportunities in the area, with a particular emphasis on supporting greater Aboriginal representation in the broader mining workforce.

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dsiunderground.com

Los Pelambres expansion to cost extra $400m, says Antofagasta

Chile copper miner Antofagasta has revised the capital cost estimate for its Los Pelambres expansion project to $1.7 billion, from the original guidance of $1.3 billion, mainly owing to revised marine works.

The project, which will add about 60,000 t/y to the mine's production, will be completed early in the second half of next year, the London-company said recently, stating that Covid-19 restrictions had impacted on the schedule.

The project would continue with only 75% of the originally planned on-site manpower to comply with Covid-19 restrictions. Construction work at the project was suspended for several months in 2020.

About $235 million of the revised cost estimate relates to changes to the marine works that were needed to enable the future expansion of the desalination plant.

Antofagasta said that the Los Pelambres expansion was 45% complete at the end of December 2020.

Meanwhile, the company reported production of 733,900 t of copper in 2020, which was in line with its guidance and 4.7% lower than the record production in 2019. Fourth-quarter output was 192,600 t.

The miner also produced 54,700 oz of gold and 3,700 t of molybdenum in the final quarter of 2020.

Net cash costs for the full year were below guidance at $1.14/lb.

Group production in 2021 is expected to be 730,000 t to 760,000 t of copper, 240,000 oz to 260,000 oz of gold and 9,500 t to 11,000 t of molybdenum.

Group cash costs in 2021 before and after by-product credits are expected to be at $1.65/lb and $1.25/lb, respectively.

Capital expenditure in 2021 is expected to be $1.6 billion, as the rate of expenditure on its growth projects accelerates following their temporary suspension in 2020, which deferred some $200 million into 2021, and higher costs at the Los Pelambres expansion project.

Fossil fuel production expected to increase through 2022 but remain below 2019 peak

In 2020, fossil fuel production in the United States declined by an estimated 6% from the 2019 record high of 81.3 quadrillion British thermal units (Btu). Based on forecasts in the US Energy Information Administration's (EIA) January 2021 Short-Term Energy Outlook (STEO), EIA expects total production of fossil fuels in the United States to remain flat in 2021 as increased coal production offsets declines in natural gas production.

EIA expects production of all fossil fuels – crude oil, coal, dry natural gas, and natural gas plant liquids (NGPL) – to increase in 2022, but forecast fossil fuel production will remain lower than the 2019 peak.

EIA's surveys measure fossil fuel production in physical units, such as cubic feet for natural gas, barrels for crude oil, and short tons for coal. Energy production is expressed in heat content units to allow comparisons across fuel types. On a heat-content basis, dry natural gas accounted for the largest share of fossil fuel production in 2020, at 46%. Crude oil accounted for 31%, coal for 14%, and NGPLs for 9%.

From the mid-1980s through 2010, coal was the leading source of US fossil fuel production, but coal production has since been surpassed by dry natural gas (in 2011) and by crude oil (in 2015). In 2020, the United States produced twice as much energy from crude oil (24 quadrillion Btu) than coal (11 quadrillion Btu) and three times as much energy from natural gas (35 quadrillion Btu).

US coal production fell by an estimated 24% in 2020, but according to EIA's forecast, US coal production will increase by 12% in 2021 and another 4% in 2022. In recent years, about 90% of US coal has been consumed by the electric power sector. In EIA's forecast, increases in natural gas prices are expected to reduce natural gas consumption for electricity generation, which will result in an increased share for coal – and to a lesser extent, an increased share for renewables such as wind and solar – in the electricity generation mix.

EIA estimates that US NGPL production increased by 7% in 2020. Newly commissioned, more efficient natural gas processing plants supported growth in NGPL production even though natural gas production declined. EIA expects domestic NGPL production to increase by 2% in 2021 and by 7% in 2022 mostly because of ethane production growth.

Commencement of early works at Havieron

Greatland Gold plc, the precious and base metals exploration and development company, has recently announced that early works activities have commenced at the Havieron Project in Western Australia.

Gervaise Heddle, Chief Executive Officer of Greatland Gold plc, commented: "The commencement of early works activities at Havieron marks a major milestone for the project and for the Company. Earth moving activities to prepare for the construction of the box cut and decline have begun and we will continue to update shareholders as work progresses. In addition, we look forward to advancing the 2021 growth drilling programme at Havieron, where mineralisation remains open in multiple directions outside of the initial Inferred Mineral Resource estimate."

The Havieron Project is operated by Newcrest under a Joint Venture Agreement with Greatland. The commencement of early works by Newcrest, as Manager of the Joint Venture, follows receipt of the necessary regulatory approvals to commence these construction activities (as announced on 29 December 2020).

Work is ongoing to finalise the Water Management Plan for the early works programme and to progress further approvals and permits which will be required to commence development of any operating underground mine and associated infrastructure at the Havieron Project. In addition, the development of any underground mine at the Havieron Project will also be subject to further studies, Board approvals and a positive decision to mine.

Rio Tinto to move swiftly to resolve Mongolian mine dispute

Rio Tinto's new chief executive Jakob Stausholm will move swiftly to strengthen the resources giant's relationship with the Mongolian government in an attempt to defuse a deepening dispute over the $8.7 billion Oyu Tolgoi copper-gold mine expansion.

In a fresh setback for Rio's problem-plagued project, the Mongolian government warned the Anglo-Australian miner it was dissatisfied with the progress of the Oyu Tolgoi underground mine expansion and was now considering revoking its 2015 mine development and financing plan unless economic returns were improved.

The plan to enlarge the Oyu Tolgoi mine has been beset by a series of delays and cost blowouts since construction began in 2019.

Mr Stausholm, formerly Rio's chief financial officer, was elevated to the CEO role at the mining giant in December. His predecessor in the role, Jean-Sebastien Jacques, was ousted last year following investor outrage over the destruction of ancient caves in the Pilbara region of Western Australia.

The new Rio CEO has made it clear that forging closer relationships with governments and greater trust with stakeholders in the countries it operates will be one of his top priorities across its global mining operations.

Coronavirus update

Demand for iron ore is expected to expand in 2021, on the back of a robust steel market in China coupled with countries recovering from the economic slump caused by the coronavirus pandemic. The iron ore price reached roughly $150 per tonne in December, escalating existing prices, which already registered an 80% growth in 2020. The steel industry in countries like India, Japan and South Korea have recovered to pre-pandemic levels already.

Demand for base metals is expected to take at least two to three years to recover to the pre-pandemic levels of 2019, according to INTL FCStone, a global bullion broker. One bright spot in the pandemic crisis is that green metals like nickel, lithium, cobalt, and copper are expected to profit as the world is shifting towards new policies following the Covid-19 pandemic.

More delays for Australia's New Hope's coal mine

Australian coal producer New Hope has warned that it may have to cut more jobs at its 4.8mn t/yr New Acland thermal coal mine, after its application to expand the mine to 7.5mn t/yr and extend its lifespan was referred back to the Queensland Land Court.

New Hope has already cut around 200 jobs, including 120 at New Acland and the rest in its corporate offices. It had hoped to be able to reinstate staff and begin work on the expansion last year but has not been able to secure final approval to move ahead with the mine. The firm is seeking a meeting with the Queensland state government to try to confirm a sanctioned plan to move forward with the expansion.

"What we need now from the government is a roadmap for how we get the project up and running because more delays equates to more job losses," said New Hope's chief executive Reinhold Schmidt.

New Hope first applied to expand New Acland in 2007 and was granted approval by Queensland's Coordinator General in 2014. But the final mining lease has been held up by several legal appeals by environmental and community groups opposed to the development.

New Acland made a negative margin during February-July and continues to face the prospect of closure because without the expansion the firm is left mining less economic coal. New Hope wrote down A$111mn ($85mn) from the value of the mine in its half-year results in July, reflecting the risk of closure and costs associated with ramping down the mine while it waits for approvals.

Australia to reform mining qualification design

The Australian Government is conducting a qualification trial to deliver faster training to the mining sector.

This is aimed to improve the national vocational education and training (VET) system.

The trial will test the concepts of qualifications that are based on grouped occupation and skills clusters, enabling broader job outcomes for people.

It will also test simplified training products that reduce the level of conditions in current qualifications, while helping students rapidly upskill or reskill to pursue new opportunities.

The Australian Minister for Employment, Skills, Small and Family Business, Michaelia Cash, said the Morrison Government was committed to delivering faster and improved training for the Australian mining sector.

"We want to better meet the current and future training needs of employers and employees, which is especially important now to support our COVID-19 economic recovery," Minister Cash said.

"That's why this trial is so important, because it will help simplify and streamline qualifications to provide the mining sector with the skills it needs to flourish."

Minerals Council of Australia (MCA) chief executive Tania Constable welcomes the trial, stating that Australian mining requires more relevant qualifications and training providers to meet changing industry expectations.

"With over one-third of the 240,000-strong mining workforce holding a Certificate III or IV qualification, improving qualification reform models is crucial for the industry," she said.

"With increasing technology adoption, workers should expect that VET sector qualifications will make them job-ready or allow them to move between jobs in the mining industry.

"Industry needs greater confidence that VET qualifications will remain relevant as the nature of work changes."

Copper to rise in 2021

Copper has been forecast to outdo the performance of other mining commodities this year, according to a White & Case 2021 survey.

The survey found that 36% of respondents expect copper to outperform other commodities, including gold (18%), lithium (14%) and nickel (12%).

Last year, copper reached its highest price in seven years due to fears that it would enter a deficit.

"As prices surged, input costs fell, creating the biggest margins for miners in years," White & Case stated in its Mining & Metals 2021 report.

According to the law firm, copper's use in electric vehicles and green technologies has also led to further demand, with demand in China reaching record highs in 2020.

The survey also found that gold deals will continue to surge in 2021, with over 40% of respondents expecting precious metals to see more mergers and acquisitions (M&A), which nearly doubled the votes that base metals received.

"Still, while our respondents expect deals, they are split on the outlook for bullion this year," White & Case stated.

The survey results indicate that large M&A are unlikely to occur outside of gold.

Gold polled the second highest votes as the commodity that was expected to outperform in 2021, however it was also the second-highest voted commodity to underperform.

"Nearly half of respondents said they expected M&A to be opportunistic and focussed on assets, rather than the big transformational deals that have reshaped the sector in the past," White & Case stated.

A total of 45.4% of respondents considered environmental, social and governance issues as the key risk for the mining sector in 2021.

"The forced departure of Rio Tinto's (chief executive) and other executives after the destruction of two ancient Aboriginal heritage sites also showed that this is an issue bigger than just climate change and pollution," White & Case stated.

RPMGlobal finalises first sale of Underground Potash Solution (UGPS)

RPMGlobal has announced it has concluded the first sale of its latest integrated mine planning and scheduling product developed for the underground potash industry.

The first sale of Underground Potash Solution (UGPS) was concluded following completion of a successful trial program with a leading global potash miner who has purchased UGPS to extract greater value from their Canadian operations. The sale follows the original release of UGPS to the market in October 2020.

UGPS was launched upon the completion of a development project which included global potash producers. The product uses the latest technologies, such as parametric design and scheduling, combined with several optimisation algorithms to create a unique offering specifically for potash operations.

Commenting on the sale, RPM Chief Executive Officer Richard Mathews said the potash industry is an important industry with the vast majority of all potash product produced being used in agriculture to fertilize food supply and improve water retention, nutrient value and disease resistance of food crops.

"It has been really fascinating working with some of the leading producers in the industry to build a software planning and scheduling solution which addresses the unique challenges faced by the potash industry," he said.

"At RPM, we continually strive to develop innovative solutions that provide a pivotal step-change in the resource industry and we are very pleased that our latest integrated mine design and scheduling solution has been endorsed by a leading potash operator in North America."

UGPS introduces to the market an enterprise application which allows users to rapidly evaluate different mine design scenarios.

Instead of having to manually draw the mine layout in a CAD package, the parametric design techniques of UGPS enable a planner to rapidly generate and analyse multiple scenarios, thereby automating the repetitive and time-consuming tasks that can often take a mine planner weeks to perform.

The intuitive, process-driven interface makes the product easy to use, and while most mine planning software is driven by customisable coding scripts, UGPS is very different given it is completely script free.

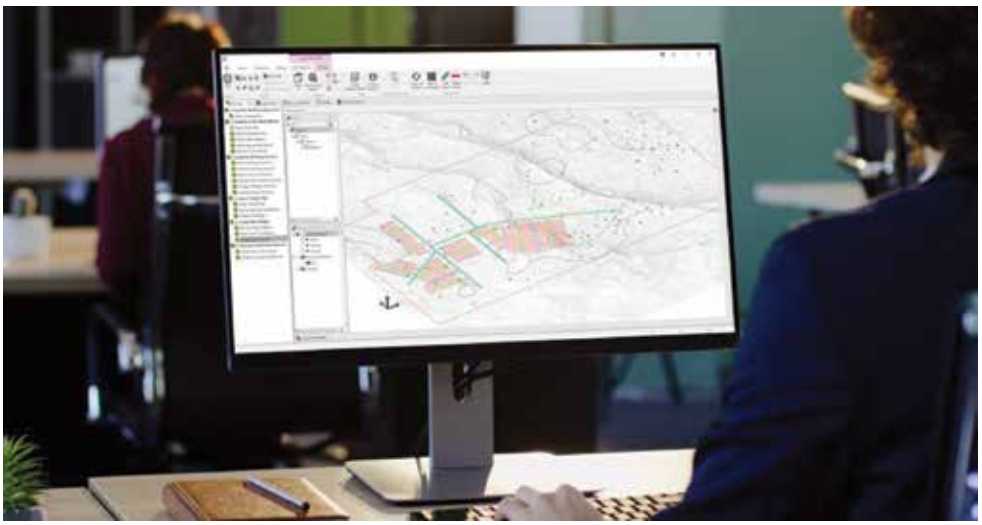
This becomes very important in terms of training and on boarding new people, enabling each customer to derive immediate benefits following implementation of the product.

Users can complete detailed modelling of their potash deposit in 3-D while also creating a complete mathematical model of the mine. Moreover, users are able to import existing designs, create new designs or use a combination of both.

UGPS also introduces advanced scheduling methodology to the scheduling process to suit the practical needs of engineers operating in an underground potash environment. It also incorporates all aspects of the scheduling process in one, making it applicable for design, reserving and scheduling across all horizons.

Mr Mathews concludes by saying: "RPM remains committed to advancing the sophistication and functionality of its industry-leading scheduling solutions, like UGPS, to provide mine planners with more capabilities than ever before."

"As a fully integrated mine planning and design tool, UGPS is tailored to the needs of the underground potash industry and we are looking forward to rolling out UGPS to additional potash operations in 2021."



Greece gets six non-binding bids for nickel smelting plant

Greece has received six initial bids for the lease of a smelting plant operated by debt-laden Larco, one of the world's biggest nickel producers, the country's privatisation agency HRADF said recently.

The deadline for the submission of non-binding bids for the Larymna smelting plant and related mining rights expired at 15:00 GMT on Monday 1 February 2021.

Commodity & Mining Insight Ireland, a consortium of GEK TERNA with Swiss-based AD Holdings, Mytilineos , Solway Investment Group, Tharisa and Trafigura Group have expressed interest, HRADF said.

Larco, which is 55% owned by HRADF, was liquidated last year, following a decision by a European Court which said Greece had failed to recover €135.8-million of illegal state aid to the company.

Last year, a special administrator was appointed to sell some of its other assets – mines, plots of land and other property – in a separate tender. The deadline for the expression of interest in that process expired on 2 February 2021.

The preferred investor in one of the tenders will have a right to outbid rival offers in the other tender under a shoot-out clause. Greece aims to have the process concluded by July 2021.

Wirtgen 220 SMi 3.8 Surface Miner – high-performance chalk mining in France

Thanks to Wirtgen's 220 SMi 3.8, scrapers and dozers require less power to load the scraper hopper.

SUCCESSFUL PERFORMANCE TESTS CONDUCTED AT HEIDELBERGCEMENT IN COUVROT WITH THE 220 SMI 3.8 SURFACE MINER FROM WIRTGEN

On behalf of the HeidelbergCement Group, Wirtgen conducted a performance test with the 220 SMi 3.8 surface miner at a chalk quarry in Couvrot. The goal was to increase production output compared to the current mining method using a crawler dozer while simultaneously reducing operating costs.

During the demo, several tests were conducted to convince the customer that the smallest Wirtgen surface miner is a viable and more efficient alternative. To do so, the surface miner's cutting performance, turning time, and fuel consumption were recorded, among other parameters.

WIRTGEN'S 220 SMI 3.8 VALIDATES HIGH EXPECTATIONS

Up until now, the company has used a bulldozer to break up the chalk in Couvrot, before a scraper loads the material into the hopper (also known as the bowl) and transports it to a temporary storage facility. From there the chalk is transported to the adjacent cement factory, where it is immediately processed.

Since the pieces of rock mined by the dozer are relatively large, with a grain size of up to 80 cm, this mining method causes several problems at once. On the one hand, it creates an uneven surface that must first be leveled by the dozer so that the scrapers can be used to load the material in the first place – an additional, extremely time-consuming task. On the other hand, the coarse grain means that the scrapers require considerable energy

Wirtgen's powerful milling drums can produce significantly smaller grain sizes than, for example, drilling and blasting or, as shown here, using a dozer.

and force to load the mined material. This primarily causes considerable traction issues for the scraper, which results, among other negative effects, in an extremely high level of wear and tear to the machine's tires. As a result, two to three dozers are currently required per shift to level the excavated area and push the scrapers. In addition to the customer's expected output of at least 500 m³ per hour, the objective was to eliminate the aforementioned problems with the help of the surface miner.

The 220 SMi 3.8 can easily handle difficult conditions – thanks to its adjustable longitudinal and cross slope, larger puddles are no problem for the machine.

The 220 SMi 3.8 surface miner is capable of selectively mining raw materials at cutting depths of up to 350 mm and a uniaxial compressive strength of up to 35 MPa. Thanks to its 3.8 m wide cutting drum designed specifically for soft-rock mining, the surface miner achieves maximum productivity at low operating costs, making the compact 220 SMi 3.8 perfect for use in small to large mining operations – a fact that it impressively demonstrated in France.

During the performance test in Couvrot, cutting zones with a length of 150 m and 300 m as well as a width of around 40 m were first mined using the 3.8 m wide cutting drum. The drum was then replaced with a 2.2 m wide drum and tested for one more day.

220 SMI 3.8 SURFACE MINER PROVES ITS SUPERIORITY UNDER DIFFICULT CONDITIONS

According to the customer, the Couvrot region receives significantly more rainfall between October and April than in the summer months. Huge puddles make it difficult to mine the chalk and the moist material has a negative effect on further processing. These conditions were simulated at the beginning of the tests. The 220 SMi 3.8 had to perform a variety of cutting tasks in muddy and wet terrain. Needless to say, the machine also mastered this challenge without any loss in performance. All of Wirtgen's surface miner models feature adjustable longitudinal and cross

While the high-performance miner extracts the chalk non-stop at an extremely high speed, the scrapers push the material into their hoppers to transport it away.

slopes, which ensures that rainwater drains off and keeps the working surface dry.

Even when cutting on slopes with a gradient of up to 16%, the production output of the 220 SMi 3.8 remained high. The machine achieved a peak cutting performance of 1400 m^3 per hour. This represents an outstanding result for the customer, since most of the quarry's mining areas are located on such steep slopes.

The fact that Wirtgen's surface miner can easily handle the average rock hardness of 20-30 MPa was clear even before the tests began. After all, it is designed for rock with a compressive strength of up to 35 MPa. But how would the machine perform under even harder rock conditions? Some areas of the quarry contain deposits of blue marl with a hardness of up to approximately 40 MPa. Another challenge for Wirtgen's miner that the 220 SMi 3.8 mastered with an advance rate of 5-10 m/min.

WIRTGEN SURFACE MINERS INCREASE PRODUCTION OUTPUT

in the final and probably most important test, the surface miner was used for an entire shift at the quarry. As part of a fleet with three scrapers and one dozer, the 220 SMi 3.8 cut at two cutting depths of 20 cm and 30 cm. Thanks to its powerful cutting drum and an engine output of 963 PS at a weight of 59,000 kg, the miner was able to produce significantly smaller and more uniform grain sizes than the dozer. The advantage of this is that the material cut smaller is easier to load than the large pieces of rock, so the scraper and dozer need less power to load the scraper hopper. In addition, the milled material lies flat on the surface, which means it no longer needs to be leveled with the dozer, saving additional time and therefore cutting costs. In addition, the surface miner produces level surfaces that make it easier to load the scraper and provide stable road surfaces for fast material transport. Thanks to the level haul roads, tire wear can also be reduced.

After completing the test, the quarry operator was more than satisfied with the results achieved by the 220 SMi 3.8. The surface miner far surpassed the target output rate of 500 m^3 per hour. In fact, at times the machine was able to extract almost three times the specified amount of chalk per hour.

Due to its outstanding cutting performance and its production of fine grain sizes and flat surfaces, the operator no longer needs to use a dozer, which increases output and reduces costs at the quarry. In addition, the flat surfaces reduce traction problems and scraper tire wear. Since the chalk is pre-crushed by the 220 SMi 3.8 at the quarry, further costs resulting from the use of crushers can be saved during further processing at the cement factory. In other words, the smallest surface miner delivers what it promises: "maximum performance and cost-effectiveness."

The surface miner mills the material and deposits it behind the machine in a windrow.

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Remote mine waste storage facility oversight

Safety audits of operational waste rock dumps and tailings storage facilities (TSF) account for a significant proportion of the workload in the SRK UK and SRK Kazakhstan Mine Waste Engineering teams.

Mine operations have found ways to continue production despite the disruptions caused by COVID-19, which begs the question; ”How can the safety and integrity of mine waste storage facilities be maintained during lockdown?”. The human, environmental, and business-continuity consequences of waste storage facility failure are so significant, operators and stakeholders need to know: 1) if the facilities are safe; and 2) what the potential consequences of failure could be, so that preventative measures can be put in place.

In normal times, our engineers spend significant amounts of time travelling to mine sites, working with the Clients to understand the waste facility designs, construction/operational practices, constraints, performance and risks, so that we can provide appropriate advice or raise concerns where required. In response to the current travel restrictions, visualisation technology has enabled us to undertake remote inspections utilising satellite and drone image data to identify ‘areas of interest’, supported by local site based teams with survey equipment and high-resolution video cameras. The survey equipment is used to measure key metrics such as slope and beach geometry, which can be compared with the latest designs and monitoring data to assess performance of the facility. We subsequently collectively review the data via group video conferencing and can determine features requiring further investigation or areas of divergence in performance.

We have formed integrated teams with the Clients and Contractors where everyone is working constructively to overcome challenges rather than delay progress. Through the use of regular video/teleconference meetings, we have built up effective lines of regular communication which is allowing review of data as it is generated and modifications to the program based upon findings/progress.

Despite significant restrictions to travel, we have remotely provided TSF inspection and design review services to our Clients in Central Asia. We plan to use ‘real-time’ observations utilising live network-linked cameras on remote site locations once network coverage becomes available, and Qualified professional engineers will subsequently follow up these remote inspections with full Dam Safety and Operational Reviews (DSOR) in person.

In addition to TSF inspections, we are also undertaking remote supervision of waste rock dump foundation investigation works which are currently underway at remote sites with difficult ground conditions. Inspection of high-quality core photographs (with high pixel density) allows us to gain understanding of ground conditions as they are encountered and to modify drilling/sampling/testing/monitoring-installation as required.

Our Clients understand that these remote services cannot fully replace a site inspection or site supervision, but they see value in continued expert input during these difficult times.

LAST LINE OF DEFENCE- A DAM BREACH DETECTION SYSTEM

A loud siren warning of a tailings dam breach should be the last line of defense. We should not rely on it alone, but if all goes wrong it may be the difference between life and death. Accordingly, and in conjunction with RST Instruments from Maple Ridge, BC, Canada, SRK has developed a new, cost-effective system to trigger an alarm at the onset of an earthen dam breach.

Leading practice in tailings dam surveillance focuses on verifying whether performance and risk management objectives are being met. This practice is based on the premise that the early identification of deviations to expected dam performance will mitigate dam safety risks by allowing adequate time for the implementation of effective remedial actions. However, while putting effort into monitoring performance and identifying early signs of dam failures is recommended, some of the latest catastrophic tailings dam failures have demonstrated that in many cases information related to the root cause of the dam failure was available, but was either not understood or not interpreted in a manner leading to early warning alarms being raised. Many owners are therefore looking for a “last line of defense” – a system that can trigger an alarm and warn downstream populations of an occurring dam failure in hopes of preventing loss of life.

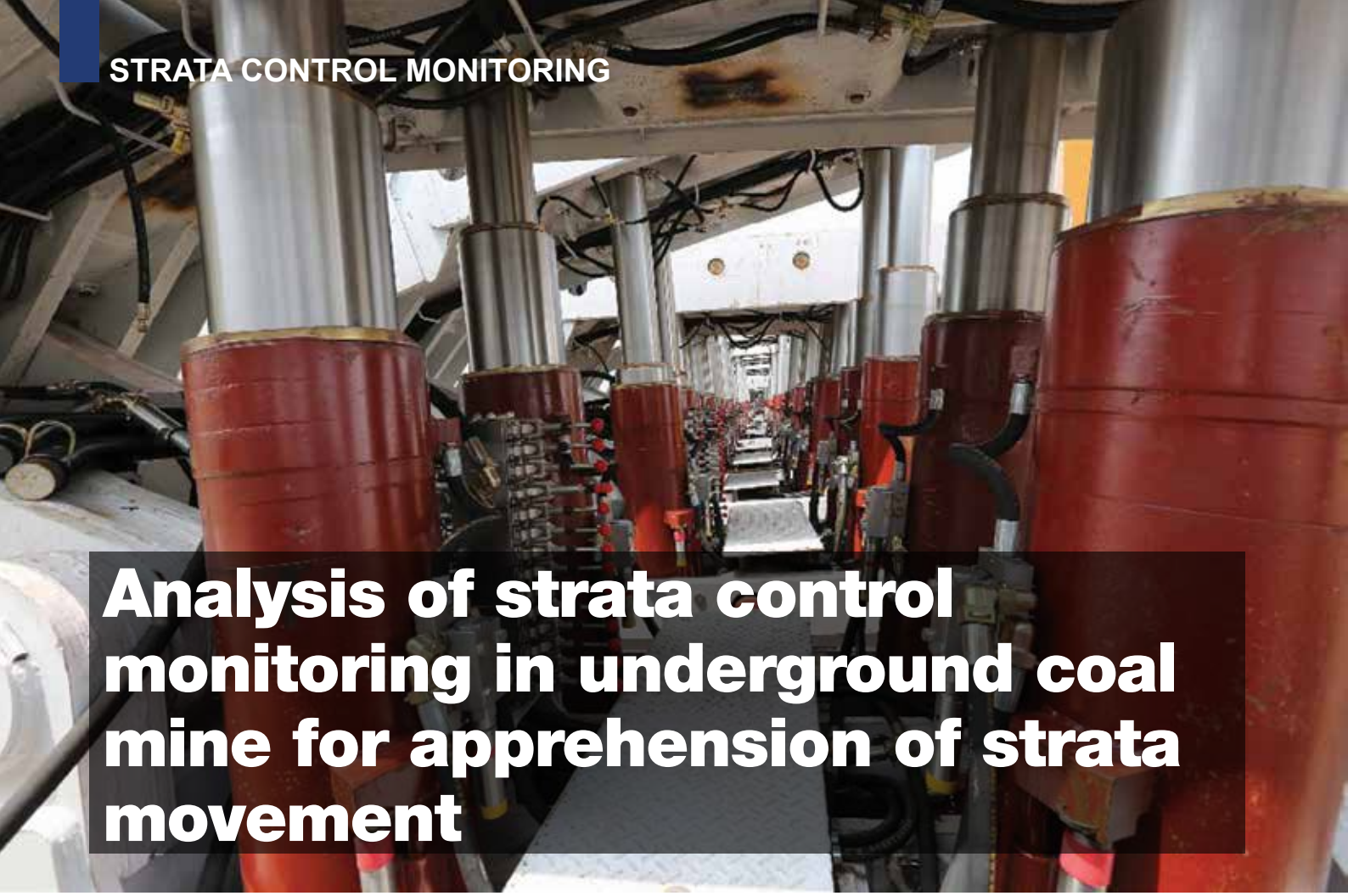
Unfortunately, many tailings dams are currently at unacceptable risk of failure and the associated risks must be mitigated and managed. The most effective means of alleviating a potential for loss of life is to relocate the population at risk. A supplementary strategy, if relocation is not possible or feasible, is to implement a siren system that will warn the population within the flood area that a dam has breached.

Nowadays, the majority of dam emergency siren systems are activated by a dam operator upon visual confirmation of a dam breach. Reliance on human intervention alone can result in a delay in triggering the alarm or, in the worst case, the alarm may not be triggered at all. SRK, together with RST Instruments, has designed and developed a simple and practical system that will set off a siren. The system comprises of several wire circuits buried in the dam crest that are connected to a datalogger, which is installed outside the dam embankment on natural ground. The datalogger verifies, at a very high frequency, whether the circuit remains uninterrupted and the wire is installed such that it will break immediately if the dam crest is mobilised due to a dam failure, causing the signal to the datalogger to be interrupted and the siren, in turn, to be triggered.

Our dam breach detection system is currently being installed in several high-risk tailings dams. The owner of these dams has relocated the populations most at risk and agreed with surrounding communities to implement the system as a last line of defense while the dams are being stabilised.

Richard Martindale (*SRK):*
Principal Geotechnical Engineer & Jamie Spears(SRK)
Senior Tailings Consultant:, Remote Mine Waste Storage Facility Oversight

Ignacio García Schmidt *(SRK):*
Senior Geotechnical Engineer



Analysis of strata control monitoring in underground coal mine for apprehension of strata movement

Final extraction in underground coal mining is associated with hazards and risks of accidents relating to fall of roof and sides due to in equal strata movement in active mining zone. Strata movement exhibits dynamism on loading effect during Bord and Pillar extraction in proportion to increase in goaf span and area leading to formation of dynamic loading zone and effect within working areas including at goaf-edges. The loading effect generally happens to be maximum near the goaf-edges with diminishing effect farther in the dynamic loading zone requiring advance support in depillaring panels. Any presence of geological disturbances or weak zones in the working area may attract release of such mining induced stress, further leading to collapses or un-eventualities. State of strong overlying rock formations may even lead to sluggish caving characteristics, enlarging dynamic loading zone with erratic strata behavior. Release of stress can be controlled by proper apprehension of strata movements including delineating, dynamic loading zone with effect and subsequent preventive measures. Strata control instrumentation and monitoring with proper analysis has emerged as a leading global solution for apprehension of strata movement during final extractions. The study deals with preliminary analysis of strata control monitoring in an Indian underground coal mine, Churcha underground mine of SECL, Coal India Limited. Depillaring in the mine is associated with constrains/difficulties such as high depth of cover, hill cap cover, geological disparities and very hard overlying rock formations. The basic objective of the study is to apprehend strata movements so that subsequent preventive measures can be initiated against any un-eventualities relating to roof and sides.

INTRODUCTION

Final extraction in underground coal mining is associated with hazards of accidents relating to fall of roof and sides due to in equal strata movement in active mining zone. Process of final extraction induces strata movement with multifold dynamism of ultimate mining stress having variability of input parameters, including size of goaf, height of extraction, depth of cover, physico-mechanical properties of overlying superincumbent, methodology of mining and rate of extraction etc. Strata behavior in case of Bord and Pillar extraction is even complicated with respect to longwall method of extraction because of left out rib pillars in the goaf as remnants and bleak-homogeneity on extraction front.

Dynamism of strata movement is experienced upon Bord and Pillar extractions, further leading to formation of dynamic loading zone and effect within working areas including at goaf-edges. The loading effect generally happens to be maximum near the goaf-edges with diminishing effect farther in the dynamic loading zone requiring advance support in depillaring panels. Any presence of geological disturbances or weak zones in the working area may attract release of such mining induced stress, further leading to collapses or un-eventualities. In addition, strong overlying rock conditions may even lead to sluggish caving characteristics, enlarging dynamic loading zone with erratic strata behavior. Such un-eventual strata characteristics can be controlled by proper apprehension of strata movement, followed by creating either adequate support resistance or release mechanism. Strata control instrumentation and monitoring with proper analysis has emerged as a leading global solution for apprehension of strata movement during final extractions.

The study deals with preliminary analysis of strata control monitoring during Bord and Pillar extraction in an Indian underground coal mine, Churcha underground mine of SECL, Coal India Limited. Depillaring in the mine is associated with constrains/difficulties enumerated as under,

a) Higher depth of cover (maximum 400m)

b) Tangential loading due to hill cap formations and subsequent in-equal cover confinement.

c) Hard and massive roof formations almost throughout in the cover (average RMR, about 70).

d) Presence of very hard Dolerite sill of a thickness of 89.88m to 162.9m within the cover, at a horizon of about 26.5 –120m above the roof level.

e) Presence of Dirt/Shale Bands in the coal making the pillar sides vulnerable for disintegration.

f) Vertically/angularly cleated coal formations giving rise to the potency of side spalling and subsequent collapses.

The basic objective of the study is to apprehend strata movements so that subsequent preventive measures can be initiated against any un-eventualities relating to roof and sides. Apart from apprehension of strata movement, the case study is an exposition of safe extraction scenario in Indian coal mining conditions. In the case study, instrumentation outcome such as dilation, convergence, load and stress are taken into different forms of analysis in one of the depillaring panels, 38LE panel of the mine.

GEOLOGY AND GENERAL INFORMATION CHURCHA MINE R.O. IS IN SONHAT COALFIELD, WHICH IS THE

eastern extension of the main Sohagpur master basin. A prominent Dolerite sill occurs roughly in the middle part of the basin. In Churcha west block, only Barakar formation and thick Dolerite sill are exposed. There are various minor and major faults and dykes existing in the seam.

38 Level East is a depillaring panel in Churcha West block of Churcha Mine R.O. with a notable fault of 1.2m downward throw, spread across the span of the panel, opposite to the line of extraction. Operations in the panel was being done with drilling- blasting and LHD combination.

Figure 1: Key plan showing the location of 38 LE panel

Particulars about the working of the panel:

- Name/No. of panel:
  38 level east panel, Churcha West
- Size of panel:
  length – 745m, width – 180m
- Height and width of working:
  height – 2m to 2.9m, width – 4.2m to 4.8m
- Size of pillar center to center:
  maximum – 50mx35m, minimum – 35mx35m
- Nature of roof and floor : Massive sand stone
- Thickness of cover:
  maximum – 236m, minimum – 208m
- Percent of sandstone in cover:
  Sandstone – 51.61%, Dolerite – 45.74%
- Crossing and Ignition point temp:
  crossing point – 1500C, ignition point – 1700C
- Expected incubation period: 10 month

Operations in the panel was being done with drilling-blasting and LHD combination.

STRATA CONTROL MONITORING IN 38 LEVEL EAST PANEL

Support System:

Advance support: All the original galleries, heightened galleries and split galleries lying within two pillars from pillar under extraction were kept supported by full column grouted roof bolts of length 1.5m and set at an interval of 1.2m between bolts. Unsupported span between the bolts and the sides of the galleries was not more than 1.2m. All, the junctions of original and split galleries lying within two pillars of working pillars were supported by full column grouted roof bolts in conjunction with 3 numbers of W-straps placed at 1.2m interval between the rows and between the bolts.

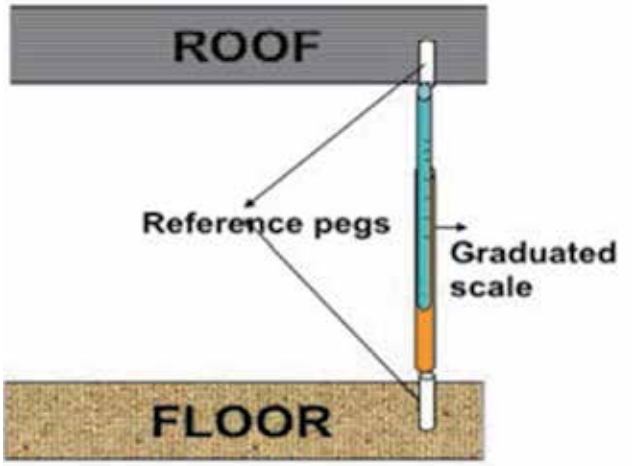


Figure 2: (a) Telescopic convergence indicator.

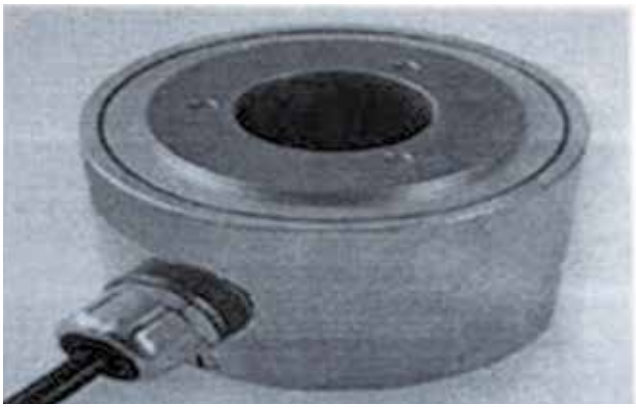


Figure 2: (b) Load cell.

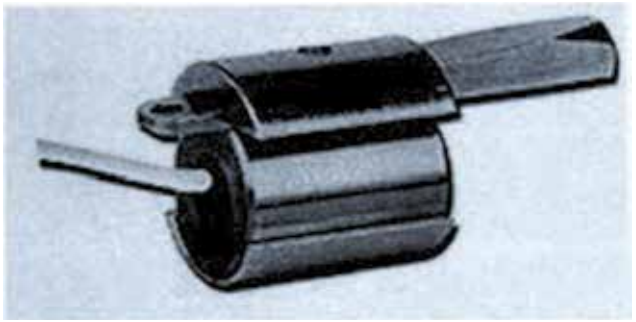


Figure 2: (c) Stress meter/Stress Cell.

At working places: For a slice before opening from the split/original gallery, the entrance was supported by 2 rows of grouted roof bolts in conjunction with 3 numbers of W-straps set at an interval of 1.2m between bolts and between rows. The slices were supported with cogs set at rib side, intervals not exceeding 2.4m.

At Goaf Edges: Integrated Steel framed cogs of 50 Ton capacity, topped by wooden sleepers not less than 30% of total height of the cogs were set skin to skin at all along goaf edges. A row of steel prop/rigid props were also set as breaker props of 20 Ton capacity, at strategic points and also at immediately behind the goaf edge cogs at intervals not exceeding 30cm. Sufficient numbers of Indicator props were fixed in goaf and other vulnerable places for apprehending thegoaf movement to take safe withdrawal of persons during goaf fall.

Instrumentation and monitoring:

Instruments used: Strata control instruments (**Figure 2**) installed in the panel, include TCI (Telescopic convergence indicator), Load Cell and Stress Cells. Installation layout is as mentioned in the instrumentation plan (**Figure 3**).

Data generation: Instrumentation monitoring was done by competent personnel round the shifts, generating enormous data/information, which was stored and processed in the integrated computer based data bank of the mine for further analysis. In addition to instrumentation outcomes, monitoring of other physical activities such as roof weighting, roof fall details and changes in working geometry was concurrently going on for further analysis.

ANALYSIS

There after the processed data from the data bank are subjected to regular analysis, every afternoon by a group of mining engineers including Strata control Engineer, Panel Engineers, Safety Officer and Colliery Manager. Principal objectives of such analysis are to,

- Identify vulnerable zones/places of load concentration.
- Trend of loading characteristics.
- Evaluation of support efficacy.
- Apprehension of dynamic/periodic load in the workings and subsequent preventive measures.

Initially, caving characteristic of hang out goaf was constrained with release of induced stress, leading to formation of hanging goaf area of about 25000 sq.m., which was a big concern from strata control point of view. The first main/major roof fall came after 75 days of start of depillaring operation, covering a goaf area of 23088.50m^2. Total 50 numbers of goaf falls were witnessed including 32 major falls. Total, 306 numbers of convergence monitors (TCIs- Telescopic convergence indicators), 36 Load cells and 16 Stress cells were installed in the panel to monitor convergence, load and induced stress during extractions. The Instruments were installed on the level and split galleries covering junctions and midways, facilitating monitoring near active goaf-edge, in due course of time and subsequent apprehension of strata movement for safe withdrawal of men and equipment from the vulnerable places.

For the study, three, out of the 36 major falls (The first one, fall in the midst of the panel and the last one) were taken into strata control analysis, apprehending strata movement for ultimate safe scenario of mining. Fall wise details (Fall A, B and C) of analysis are as follows.

Major roof fall – A, dated 28.09. 2013 (Goaf area of fall – 23088.50m^2)

Major roof fall on dated 28.09.2013 was the first main fall of the panel, which occurred covering a goaf area of 23088.50m^2. Analysis of convergence, apprehending the fall was done based on readings from Telescopic Convergence Indicator(TCI) stations at 39 ½ L / 19 X cut Junction, 39LW / 20 X cut Junction and 38L / 21 X cut Junction (ref. instrumentation plan, **Figure 3**) Convergence profile at 39 ½ L / 19 X cut junction (**Figure 4**) confirms the following outcome.

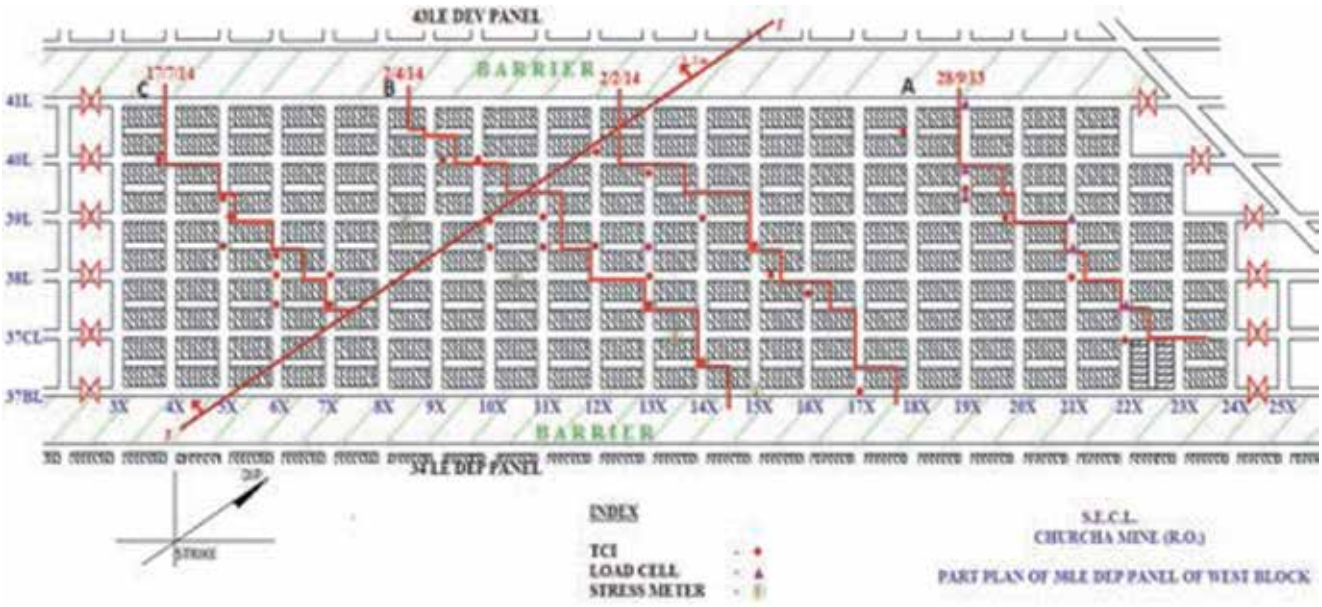


Figure 3: Instrumentation layout plan.

Dynamic loading influence of goaf upon workings was started with a rate of change in convergence of 8mm / day on 19.09.2013, i.e. 10 days before the main fall, while the monitoring station was about 70m away from goaf edge.

- Highest daily and cumulative convergence of 14mm / day and 74mm was recorded on 27.09. 2013, a day before main fall, the station being about 30m away from goaf edge, which indicates breakage of roof stratum facilitating main fall.

Convergence profile at 38 L / 21 X cut junction (**Figure 5**) confirms the following out come

- Dynamic loading influence of goaf upon workings became active with a rate of change in convergence of 11mm / day on 20.09.2013, i.e. 11 days before the main fall, while the monitoring station was about 50m away from goaf edge.

was observed at 40 L / 19 X cut junction with peak daily and cumulative load of 1.65 Te. / day and 7.84 Te near goaf edge, on 27.09.2013 and 28.09.2013 respectively, stating, periodic weight of dynamic loading on workings for a period of 5 days before main fall. it is ascertained that a repetitive loading effect was there in this part of the workings, leading to a local fall on 20.09.2013 with daily load of –0.02 Te. There was a peak, daily and cumulative load of 1.89 Te. and 6.15 Te. on 27.09.2013 and 28.09.2013 respectively, before main fall. Negative loading effect on 29.09.2013 indicates release of stress, induced of extraction and subsequent dynamic loading.

- Maximum daily convergence of 14mm / day was observed on 23.09.2013 and the loading effect was very active upto 26.09.2013, i.e. 3 days before fall, which indicates breakage of roof stratum by then, facilitating main fall.
- Peak cumulative convergence of 109mm was observed at the time of main fall on 28.09.2013, the station being about 10m away from the goaf edge.
- Smooth and gradual dynamic loading influence of goaf upon workings was observed at this station.

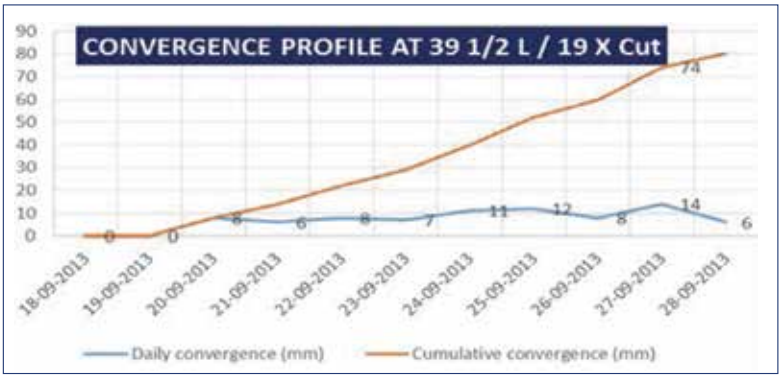


Figure 4: Convergence profile at 39 ½ L / 19 X cut.

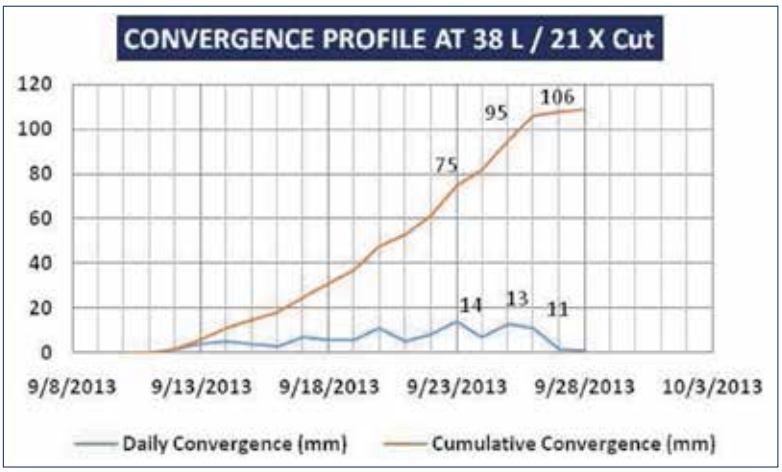


Figure 5: Convergence profile at 38 L / 21 X cut.

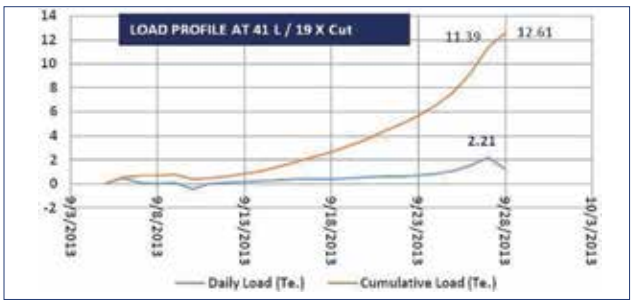


Figure 6: Load profile at 41 L / 19 X cut.

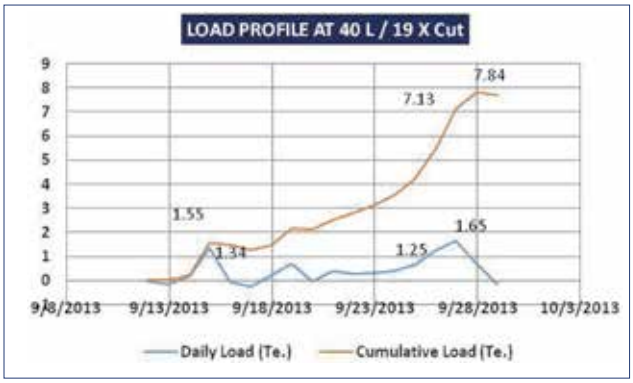


Figure 7: Load profile at 40 L / 19 X cut.

- Maximum daily convergence of 16mm / day was observed on 27.09.2013, i.e. 2 days before fall, which indicates breakage of roof stratum by then,

- Peak cumulative convergence of 124mm was observed at the time of main fall on 28.09.2013, the station being at goaf edge.

Convergence profile at 41 L / 19 X cut junction (**Figure 6**) confirms the following outcome.

Analysis of load on support system, apprehending the fall was done based on readings from Load Cells, installed on cog supports at 41 L / 19 X cut, 40 L / 19 X cut, 38 ½ L / 21 X cut and 37 1/2 CL / 22 X Cut (ref. instrumentation plan, **Figure 3**).

Referring to **Figure 11**, gradual effect of dynamic loading was observed at 41L / 19 X cut with peak,daily and cumulative load of 2.21 Te. / day and 12.61 Te., respectively, near goaf edge, indicating breakage of roof stratum, a day before main fall. Referring to **Figure 7**, repetitive loading effect

Referring load profile at 38 ½ L / 21 X cut (**Figure 8**),

Load profile at 37 ½ CL / 22 X cut (**Figure 9**) says about a longer period of loading effect on the workings for about 6 days before the main fall, due to hanging goaf and barrier side of the panel. There was a peak, daily and cumulative load of 1.89 Te. and 8.66 Te. on 28.09.2013, before main fall.

Major roof fall –B, dated 02.04.2014 (Goaf area of fall– 7949m^2)

Major roof fall on dated 02.04.2014, covering goaf area of 7949m^2 had intersected a long fault plane, which had crossed the panel by length; almost diagonally, (Ref. **Figure 3**). Apprehension of roof fall

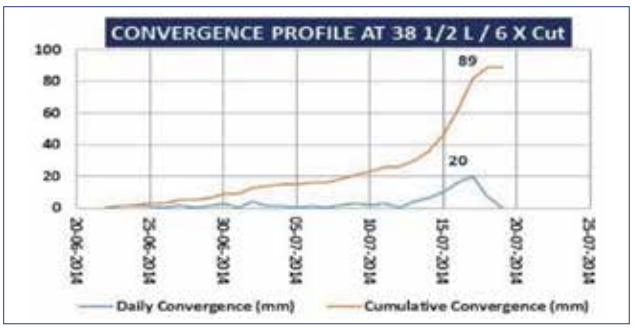


Figure 8: Load profile at 38 ½ L / 21 X cut.

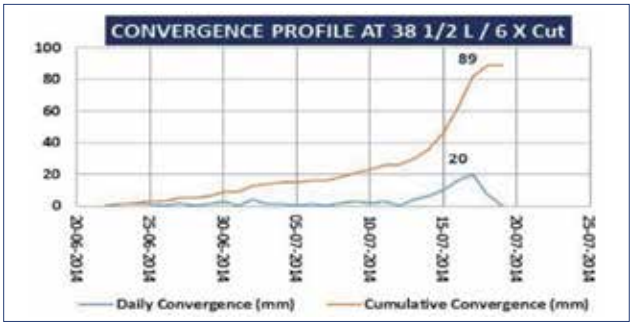


Figure 9: Load profile at 37 ½ CL / 22 X cut.

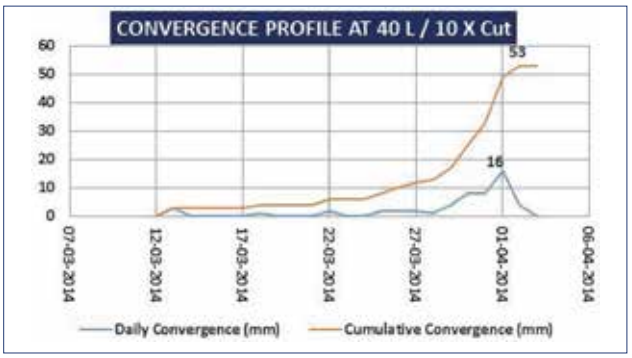


Figure 10: Convergence profile at 40 L / 10 Xcut.

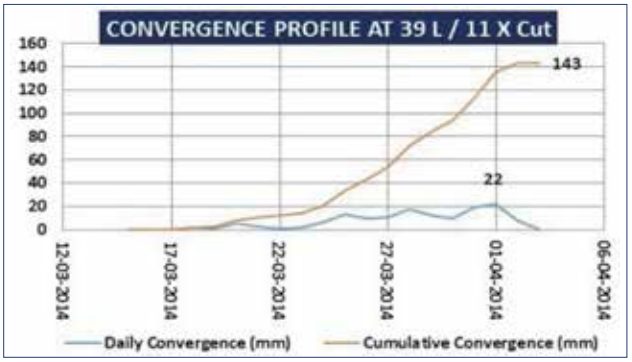


Figure 11: Convergence profile at 39 L / 11 X cut.

was done analyzing convergence from stations at 40 L / 10 X cut, 39 L / 11 X cut and 38 L / 13 X cut and stress from stations at 38 LE / 10 -11X cut, 39 LE / 8-9 X cut and 37 CL / 13-14 X cut.

Convergence profile at 40 L / 10 X cut (**Figure 10**) indicates peak loading effect upto 01.04.2014, a day before main fall with a daily rate of change in convergence of 16mm / day and cumulative value of 53mm on the day of main fall. Analysing the convergence profile at 39 L / 11 X cut

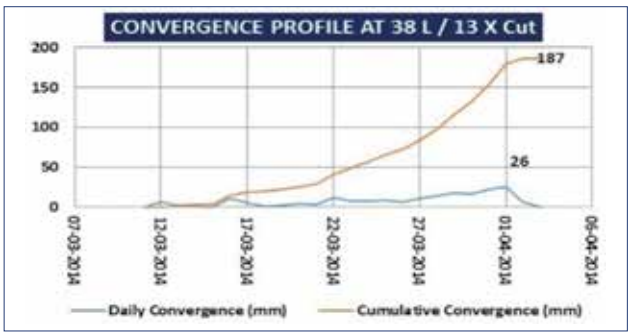


Figure 12: Convergence profile at 38 L / 13 X cut.

Figure 13: 38 LE / 10-11 X cut.

Figure 14: 39 LE / 8-9 X cut.

Figure 15: 37 CL / 13-14 X cut.

(Ref. **Figure 11**), it was ascertained that period of dynamic loading effect was for about 9 days before main fall and there was a peak daily and cumulative convergence of 22mm on 01.04.2014 and 143mm, on the day of fall respectively. Such long period of loading effect and high value of convergence indicates influence of the geological disturbance (Fault line) nearby Convergence profile at 38 L / 13 X cut (**Figure 12**) indicates peak loading effect upto 01.04.2014, a day before main fall with very high value daily rate of change in convergence of 26mm / day and

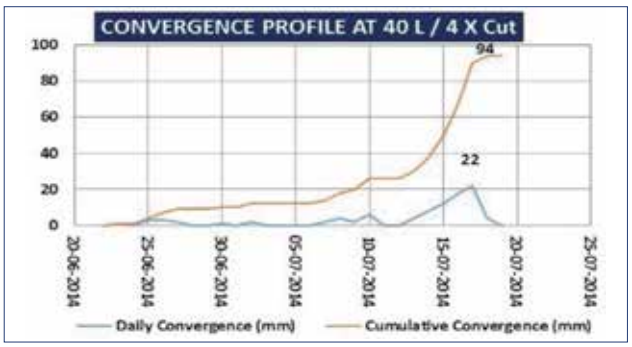


Figure 16: 40 L / 4 X cut.

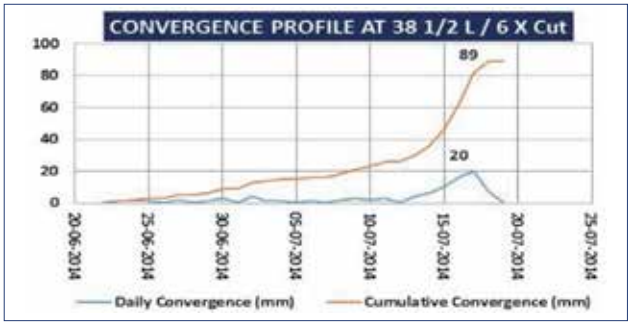


Figure 17: 38 ½ L / 6 X cut.

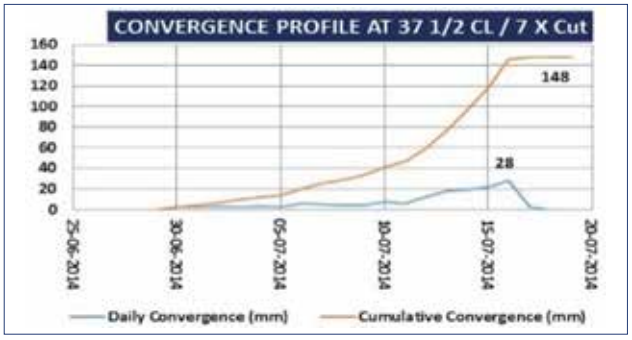


Figure 18: 37 ½ CL / 7 X cut.

cumulative value of 187mm on the day of main fall. The high value of convergence indicates the influence of the geological disturbance on the loading effect. Referring **Figure 13**, **14** and **15**, stress profiles at 38 LE / 10-11 X cut, 39 LE / 8-9 X cut and 37 CL / 13-14 X cut, indicate peak daily stress and cumulative stress as 2.8, 2.96 and 3.55 ksc / day 17.51, 17.57 and 18.08 ksc respectively. Abrupt reduction of stress in all the stress cells, on 03.04.2016, just after the fall says about a major main fall with complete release of induced stress.

Major roof fall –C, dated 17.07.2014 (Goaf area of fall – 6343m^2):

Major roof fall on dated 17.07.2014, covering goaf area of 6343m^2 refers to one of the main falls to the end of extraction in the panel. As per extent, this fall was having origination from the fault plane in the panel, already discussed, (Ref. **Figure 3**). Apprehension of roof fall was done analyzing convergence from stations at 40 L / 4 X cut, 38 ½ L / 6 X cut and 37 ½ CL / 7 X cut.

Referring **Figure 16**, **17** and **18**, convergence profiles at 40 L / 4 X cut, 38 ½ L / 6 X cut and 37 ½ CL / 7 X cut, indicate peak daily and cumulative convergence as 22, 20 and 28mm / day and 94, 89 and 148mm respectively. High value convergence at 37 ½ CL / 7 X cut says about influence of the geological disturbance (Fault plane) on extraction.

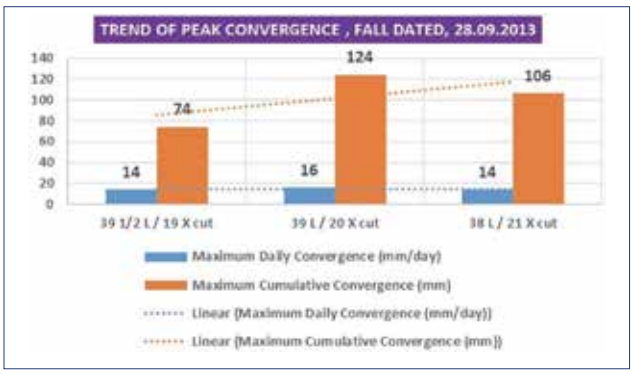


Figure 19: Trend of Peak Convergence (Fall-A).

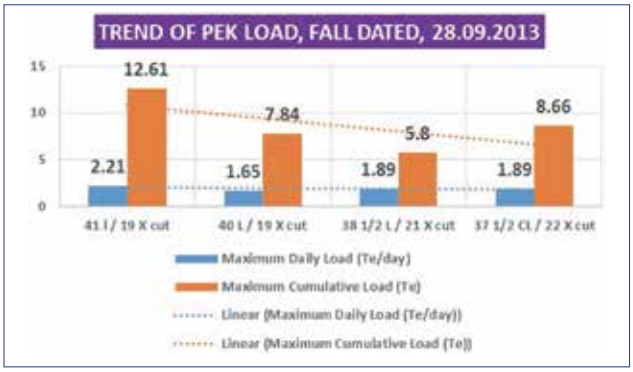


Figure 20: Trend of Peak Load (Fall-A).

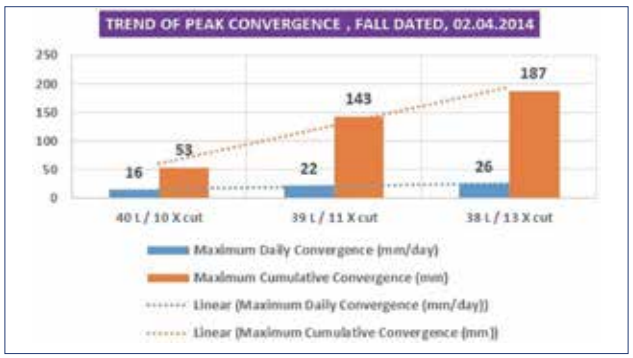


Figure 21: Trend of Peak Convergence (Fall-B).

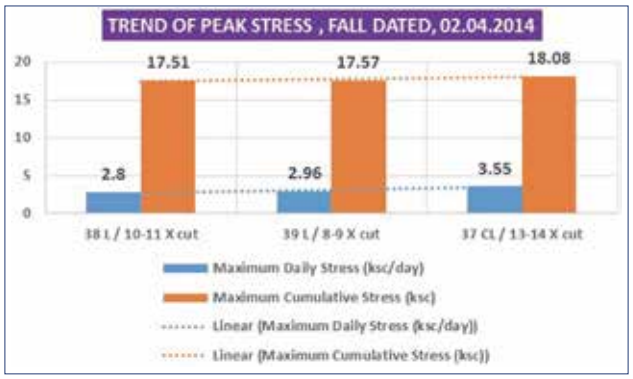


Figure 22: Trend of Peak Stress (Fall-B).

DISCUSSION

Analysing further, the trends of peak strata control parameters are as follows. Referring **Figure 19**, trend of peak convergence during Fall- A (dated 28.09.2013) gives an inference that attainment of a range of 14-16mm/ day of daily convergence and 74-124mm of cumulative convergence was an indication of first main fall, covering a vast hanging area of goaf (23088.5m2). Similarly referring **Figure 20**, a range of 1.65-2.21 Te / day of daily load and 5.8-12.61Te of cumulative load was the indication of the first main fall.

Referring **Figure 21**, trend of peak convergence during Fall – B (dated 02.04.2014) gives an inference that attainment of a range of 16-26mm/ day of daily

convergence and 53-187mm of cumulative convergence was the indication of the main fall, covering a hanging area of goaf (7949m^2), which was intersected by a prominent fault plane, across the panel. Similarly referring **Figure 22**, a range of 2.8 ksc / day of daily stress and 17.51 – 18.08 ksc of cumulative stress was the indication of the same main fall. The high peaks of convergence and stress were the attribution of the prominent geological disturbance.

Referring **Figure 23**, trend of peak convergence during Fall-C (dated 17.07.2014) gives an inference that attainment of a range of 20-28mm / day of daily convergence and 89-148mm of cumulative convergence was the indication of the main fall, covering a hanging area of goaf (6343m^2), which was representing the end of extraction in the panel.

Summarily, based on such profile and trend analysis and mine observations during periodic weighting, further intense assessment was taken up to land with local warning limits of various parameters to draw out lines of 'do's and 'do not's of operations for safe withdrawal of men and equipment from vulnerable zones ensuring safety. Such local warning limits are highly situation and place specific and subjected to intense scientific validations. However, as a mine practice and pertinent to the panel, the local warning limits taken into apprehension are as follows.

- Rate of change in convergence of 6mm / day on the level galleries and 10mm / day on the dip-rise galleries, in general, during extractions in the panel.
- Rate of change in convergence of 10mm/day on the level galleries and 12mm/day on the dip-rise galleries, during extractions near prominent geological disturbances.
- 50mm of cumulative convergence at any place of workings during extraction was taken as an local warning limit for strata movement.
- Rate of change in stress of 0.5 ksc / day and cumulative stress of 5 ksc at any place of extraction, were taken into limits of apprehension of active strata movement.

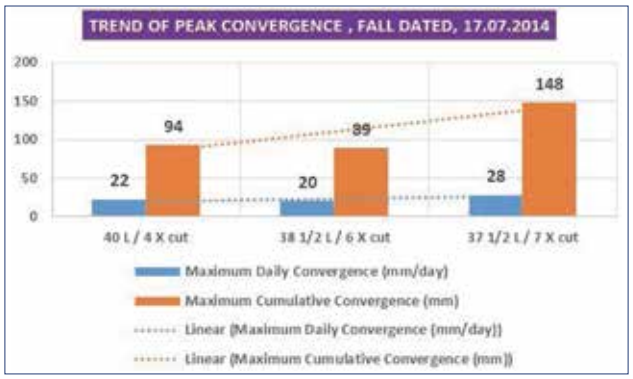


Figure 23: Trend of Peak Convergence (Fall-C).

CONCLUSION

Issues relating to strata control tend to be very uncertain in terms of underground coal mining. Many unseen geo-technical factors may also influence, strata behavior during final extractions, making the situations complex and vulnerable for strata failures, leading to un-eventualities. Prevention of all these necessiates ultimate mining practices, which are based upon proper work experience and scientific knowledge of the practitioners / professionals. Apprehension of strata movement is the basic requirement on scientific approaches for prevention of accidents due to fall of roof and sides. Intense scientific studies for apprehension of such strata movement may require strategic actions including a considerable span of time, limiting it for urgent hours of need. In addition, this necessitates a preliminary level of strata control assessment / analysis equipping the technocrats at operational front, which has become an effort at Churcha, underground mine of SECL, the study area of the paper.

This effort of preliminary strata control analysis has equipped the mine with early apprehension of strata movement, not only further preventing related accidents, but also enhancing safety awareness and confidence level of operational people in the mine.

ACKNOWLEDGEMENT

Authors acknowledge the whole-hearted support extended by Sri J P Dwivedi, General Manager, Baikunthpur Area and Srhi Y Athiya, Strata control officer, Church UG Mine, SECL during the study and collection of relevant data.

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Drill deeper, drill safer

The drills conventionally used in quarries are designed to operate at a bench depth of about 12-15 meters. Trying to penetrate much deeper can cause Down-The-Hole and tophammer drills to deviate, creating accuracy and potential safety problems.

So when drilling and blasting contractor FDDF recognised there was a push to dig deeper at some of the limestone quarries on the South Shore of Montreal, the Quebec-based company started a hunt for new drilling technology. Distributors in North America came up empty handed, so president David Habib and his partners Guillaume Ayotte-Pinard and Simon Forget looked to Europe and Japan instead.

Their search lead to the discovery of Epiroc's *SmartROC C50*, a drill rig used widely in European quarries but practically unheard of across the pond. The SmartROC C50 uses unique COPROD technology to deliver speed, efficiency and safety under demanding conditions. The drill cycle is fully automated, reducing the dependency on the operator to get the depth and angle of the hole just right.

"We actually found (Epiroc's) SmartROC C50 system on You Tube," said Habib. "We ended up going to Belgium to see the drill operating at a quarry there and we came back convinced we could use it here at an advantage."

FDDF (formerly Forage & Dynamitage Daniel Fortin) took the bold step of purchasing the SmartROC C50 and having it shipped to Montreal in August 2019, the first in Canada (and possibly North America) to do so. As a result, the growing company won the contract to drill up to 30 metre meter benches at three of its customer's bigger quarries, largely because the engineer responsible for certifying the deeper drilling and blasting deemed the plan safe using the SmartROC C50 and its COPROD technology. The three quarries produce about 2.5-3 million tonnes of limestone per year.

"The SmartROC C50 drill rig produces drilling logs in real time, so as soon as we've finished drilling, we know the deviation of the hole and the hardness of each section of the rock. With this information, we can load the explosives in each hole quite precisely. The more precise the blasting, the safer it is, and the less flyrock we have."

Controlling noise and vibration levels and limiting flyrock are particularly important in populated areas such as the South Shore of Montreal, where FDDF operates near residential neighbourhoods.

Habib also appreciates the SmartROC C50 rig's built-in Hole Navigation System (HNS), which allows his drillers to locate the correct drillhole location automatically without risking injury at the face.

> "When we submitted our proposal to the customer, the safety of the SmartROC C50 system helped us to win the contract. It gave us an edge over our competitors."

***David Habib** , President, FDDF (formerly Forage & Dynamitage Daniel Fortin)*

But quarries are not the only market for the rig.

FDDF also won the contract to dig a highway tunnel under the city of Montreal. There was zero allowance for deviation along the outline of the 25-meter-deep shafts at either end of the tunnel and so, again, the precision of the SmartROC C50 drill provided a critical advantage.

Habib said the difference between the SmartROC C50 and a conventional drill rig is like the difference between a Formula One racecar and a regular automobile. The time FDDF saves drilling lines, and the precision and safety features so appreciated by his customers, more than make up for the added capital expense.

FDDF is Habib's third drilling and blasting venture. He bought the company from the previous owner, Daniel Fortin, in 2015. Since then, FDDF has grown from six workers in high season to 35-40 today. The company's revenue has expanded about sevenfold over the same time period.

In the past three years, FDDF has invested heavily in new technology. Besides the SmartROC C50, the drilling and blasting contractor bought a second jumbo rig from Epiroc and two rock splitters from Japan.

"With such a wide range of tools, we can expand our services."

FDDF uses Epiroc drill rigs exclusively. The fleet of about a dozen rigs includes several *FlexiROC T40* tophammer drills for construction projects and medium sized quarries, and *Boomer 282* Face drill rigs for undergoing mining and tunnelling jobs.

"Any good blaster will tell you that the first step is to start with a good drill,' said Habib. "In our company, we have an expression: 'une foreuse est jaune' (a drill is yellow)."

Russian trucks pave way for greener construction

Researchers from T.F. Gorbachev Kuzbass State Technical University (KuzSTU) and Bauman Moscow State Technical University have developed multi-tonne dump trucks for quarrying.

Specialists from leading Russian universities are confident that the new dump trucks will greatly reduce transport costs and environmental impact, the press service of KuzSTU reported.

Quarrying is a big industry for many regions and countries. According to experts, it is an ideal candidate for automation which, in turn, will improve energy efficiency and the environmental effect of production.

Scientists from two universities, TF Gorbachev Kuzbass State Technical University (KuzSTU) and Bauman Moscow State Technical (BMSTU), are developing a family of robotic quarry dump trucks. Their production is planned to be launched by truck-maker, Kamaz PJSC.

"We have planned for two models of unmanned dump truck: one with an electromechanical transmission, an energy storage unit with 90 tonnes load-carrying capacity, and the other with an electromechanical transmission based on a sequential hybrid scheme with a 60-tonne load-carrying capacity. Their task is to work in open-pit operations," said Dmitry Dubinkin, associate professor of KuzSTU's Department of Cutting Machines and Tools and head of its Digital Technologies Research Centre.

According to the developers, the dump trucks will be equipped with an autonomous control system featuring a dozen modules and subsystems: 2D road mapping, remote control, route-planning module to the target point, etc.

Scientists intend to improve the efficiency and environmental friendliness of production by using specially developed electric motors. According to them, this will significantly reduce transportation costs, which make up a large part of the total price of production.

"Dump trucks with electric motors may have various energy sources, but the use

of energy storage units – cells or capacitors – will lead to the most considerable savings compared with internal combustion engines and will also have a positive impact on the environment. Furthermore, the choice of storage units will reduce the cost of installing the power grid and facilitate operations in adverse weather conditions," the director of KAMAZ-BMSTU Research and Educational Centre, Alexander Kartashov said.

Prototype testing of the KAMAZ unmanned quarry dump trucks will be carried out by Russian businesses JSC HC "SDS-Ugol" and Siberian Coal Energy Company (SUEK). Mass production of new models is planned after testing is completed in 2022.

Specialists from KuzSTU's Digital Technologies Research Centre are engaged in developing automation of industrial systems and the introduction of modern methods of production control.

"The Digital Technologies Centre is not just a project to create new technologies; it is a new practise-oriented educational platform where we will prepare unique specialists capable of combining competencies in mechanical engineering, mining engineering and digitalisation," Alexey Yakovlev, KuzSTU's acting Rector, said.

Top students and leading young scientists of the university are actively involved in the work of the centre.

Ex-Anglo CEO appointed to Glencore board

Cynthia Carroll, the former CEO of Anglo American, has been appointed to the board of diversified mining and marketing company Glencore.

Carroll would join the board with immediate effect and would serve as a nonexecutive director, the Swiss-based group announced recently.

"The directors are very pleased to welcome Cynthia Carroll to our board. She has extensive knowledge of the resources industry, as well as strong nonexecutive director experience," said chairperson Tony Hayward.

Carroll has more than 30 years' experience in the resources sector. She began her career as an exploration geologist at Amoco before joining Alcan. She held various executive roles there culminating in being CEO of the Primary Metal Group, Alcan's core business. From 2007 to 2013, she served as CEO of Anglo American.

Carroll is currently a nonexecutive director of Hitachi, Baker Hughes Company Pembina Pipeline.

Mining job seekers consider move to renewables

Almost half of the mining industry's workforce is considering a move to renewables, according to a recruitment report.

The 2021 energy outlook report by Oilandgasjobsearch.com and Brunel contains a survey of 22,000 employees across the mining and oil and gas sectors.

It found that 73% of those surveyed are looking to move jobs, compared with 56% in the previous year.

A move to green energy was the key driver for workers who are looking to seek new roles, the survey found.

Almost half of the 37% of jobseekers that listed renewables as a field they would consider moving into were from the mining industry.

The survey found that younger workers were attracted to greener sectors due to their longer-term stability.

"In particular, younger workers are attracted by the longer-term, more stable employment options on offer with renewable companies, and the fact that sectors like solar power or offshore wind are at the forefront of technological innovation makes them even more attractive," the report stated.

"On top of this, an increasing percentage of new graduates are highly aware of, and motivated by, the threat of climate change."

The report suggested that resources companies should provide high-quality training, career development programs and benefits to allow young people to compete with highly skilled jobseekers.

The survey also found that global mobility slowdown was a key trend.

Role location was listed as "top concern" for jobseekers in the resources industry, however only 14% of the mining sector stated that they are looking to avoid excess travel.

The report stated that it "(remained) to be seen" whether the mobility slowdown was caused by the COVID-19 pandemic or a speeding up of existing trends.

A total of 58% of respondents that were asked how they would respond to diseases similar to COVID-19 in the future said they would consider finding other job opportunities, employers and locations.

"This shift affects not just day-to-day travel, but also the willingness or ability of workers to permanently relocate or take short-term expat contracts due to closed borders between many states – a trend that will most keenly affect the oil & gas and mining sectors," the report stated.

Online interactive conveyor training

Conveyor operators and facility managers can obtain continuing education credits from the online training sessions.

COVID-19 has introduced a number of hardships on bulk material handlers, including limiting their options for critical training to improve conveyor safety and productivity. With in-person visits curtailed for the foreseeable future, Martin Engineering has developed an extensive array of tools to continue its decades-long tradition of educating those who maintain, manage and design conveyors for industrial operations. The result is a wide range of globally-available options to help improve safety and efficiency, reduce maintenance expenditures and extend equipment life, ultimately contributing to greater profitability.

"The pandemic has impacted our ability to teach traditional classes at customer sites," explained PE Todd Swinderman, CEO Emeritus of Martin Engineering and an industry veteran with more than 40 years of hands-on experience. "But it doesn't reduce the need for conveyor operators and facility managers to obtain the benefits and continuing education credits those sessions provide."

In response to the restrictions that the virus has placed on face-to-face learning, Martin has created a series of interactive online modules based on the same non-commercial curriculum that has served bulk material handlers so well over the years. Designed to keep attendees engaged and organized into 90-120 minute segments, the virtual classes cover topics such as best practices for safety, fugitive material control and belt tracking. Upon completion, attendees are eligible to receive either Professional Development Unit (PDU) or Continuing Education Unit (CEU) credits.

"The Foundations™ online seminars deliver non-commercial, topic-specific problem-solving information that can be put to immediate use," said Swinderman. "There's no sales pitch, and even the most remote locations can take advantage," he added.

"Conveyors are one of the best productivity-enhancing tools available, but conveyor injuries cost employers millions of dollars annually," observed Customer Development Manager Jerad Heitzler, an instructor of Martin's safety workshops since 2010. "Because of the size of their material cargos, the speed of their operation, and the amount of energy they consume and contain, conveyors have been shown to be a leading cause of industrial accidents, including serious injuries and fatalities. But injuries are preventable with the right training, preparation and safety precautions."

According to Heitzler, the company's preferred platform is Zoom, but its expert trainers also have experience with Google Meet, Microsoft Teams and Webex. "We like Zoom,

because it provides the best experience for the learner," he continued. "It integrates very well with our marketing software HubSpot, so learners can easily register using Martin URLs. We can also prepare specialized content that is highly valuable to them, including sharing job stories, additional content videos, relevant blog articles and Foundations book downloads."

"Our platform has been built to increase attendee engagement as much as possible," Heitzler added. "Many trainers don't use the available platform features effectively, because they were thrust into online training as a result of the pandemic. But we've worked hard at using engagement features to increase learner participation, with options such as a raise hand button, chat, Q and A, screen sharing, white boards, private breakout rooms and polling."

Martin Engineering has created a series of online modules for remote conveyor training.

Heitzler said that the Martin team has taught approximately 2,000 attendees using video conferencing since the onset of the virus. "We've presented these modules to learners in coal handling plants, cement manufacturing, aggregate production and pulp and paper mills," he said. "We've also provided training for industry consultants, service providers and engineering firms who design conveyors and plants."

The company also engages with customers in a variety of other ways, including free webinars on critical concepts and best practices, as well as blog posts with insights by leading professionals detailing their experiences in the bulk handling industry. Customers can always reach Martin's industry experts via phone, live chat, email or social media, and its industry reference books in the Foundations series can be downloaded in any of five languages from the company's website at no charge.

Martin has a long history of investing in conveyor training for its customers since putting out its first problem/solution literature in the 1980s. The company followed up with its first edition of Foundations in the 1990s, a 500+ page volume that has become an internationally-recognized resource for safety, maintenance and operations training – with more than 20,000 print copies in circulation around the world. Swinderman estimates that the firm has trained more than 50,000 miners, operators, maintenance staff and management personnel around the world.

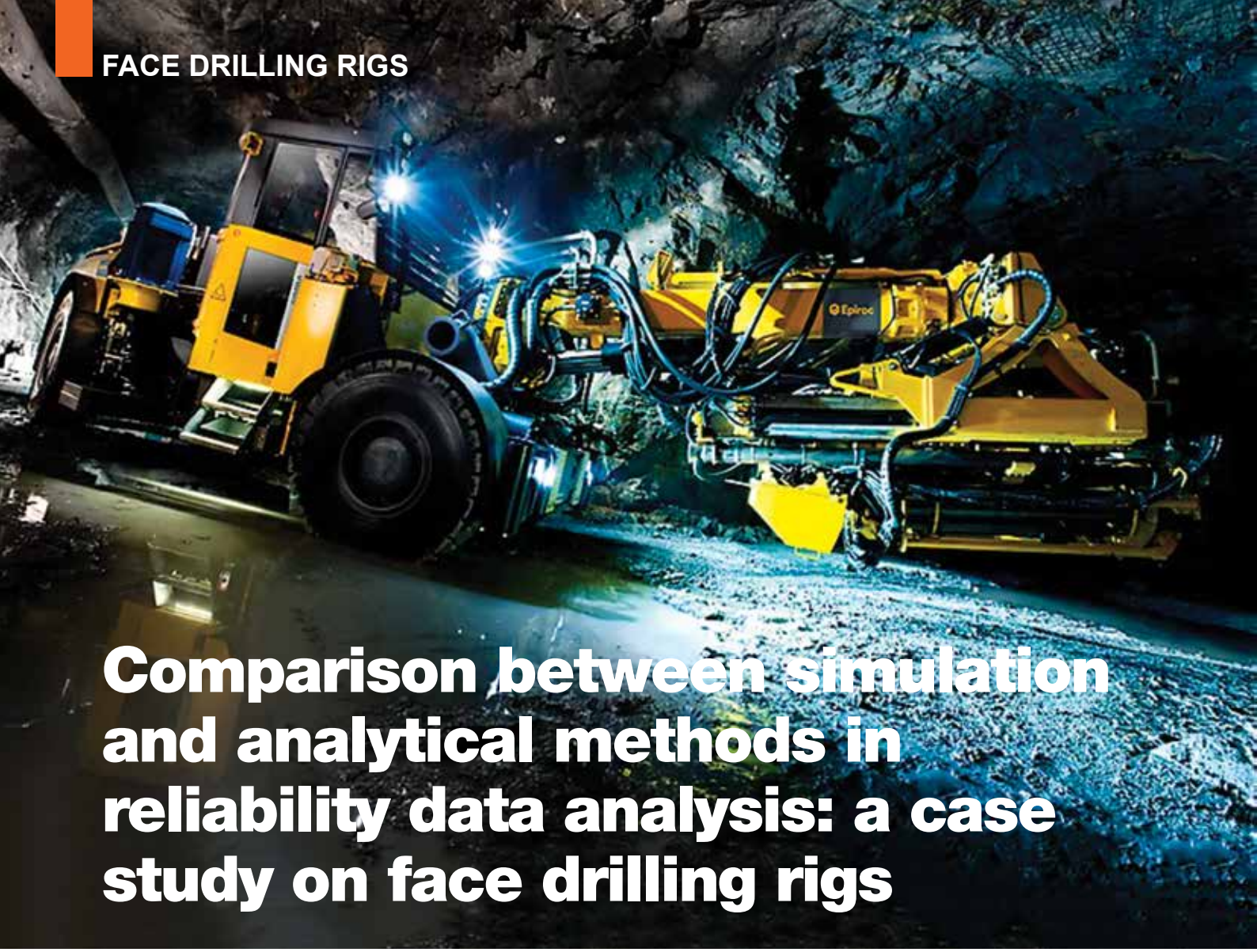
There are two standard tracks, one for maintenance and operations personnel that stresses safe work practices and solutions to common conveyor problems, and one designed for technical and management personnel that emphasizes the design and operation of conveyors for safety and productivity. In addition, Martin trainers and engineers can custom design programs not only for customers using conveyors but for those needing training on the application of industrial vibration, air cannons and silo cleaning.

"Both methods of training are highly interactive, effective and non-commercial, focusing on delivering timely information that can be put to immediate use," Swinderman concluded. Training can be provided in a number of languages, with details available from regional Martin Engineering locations. For more information on available offerings or to schedule a session visit: https://www.martin-eng.com/content/page/546/conveyor-system-training-education or call (309) 852-2384.

Martin Engineering is a global innovator in the bulk material handling industry, developing new solutions to common problems and participating in industry organizations to improve safety and productivity. The company's series of Foundations books is an internationally-recognized resource for safety, maintenance and operations training – with more than 20,000 print copies in circulation around the world. The entire 500+ page volumes can also be downloaded as free PDFs from the Martin web site. Martin Engineering products, sales, service and training are available from 19 factory-owned facilities worldwide, with wholly-owned business units in Australia, Brazil, Chile, China, Colombia, France, Germany, India, Indonesia, Italy, Japan, Mexico, Peru, Russia, Spain, South Africa, Turkey, the USA and UK. The firm employs more than 1,000 people, approximately 400 of whom hold advanced degrees.

For more information, contact info@martin-eng.com, visit www.martin-eng.com, or call (800) 544-2947.

The online seminars deliver topic-specific problem-solving information, with no sales pitch.



Comparison between simulation and analytical methods in reliability data analysis: a case study on face drilling rigs

Collecting the failure data and reliability analysis in an underground mining operation is challenging due to the harsh environment and high level of production pressure. Therefore, achieving an accurate, fast, and applicable analysis in a fleet of underground equipment is usually difficult and time consuming. This paper aims to discuss the main reliability analysis challenges in mining machinery by comparing three main approaches: two analytical methods (white-box and black-box modeling), and a simulation approach. For this purpose, the maintenance data from a fleet of face drilling rigs in a Swedish underground metal mine were extracted by the MAXIMO system over a period of two years and were applied for analysis. The investigations reveal that the performance of these approaches in ranking and the reliability of the studies of the machines is different. However, all mentioned methods provide similar outputs but, in general, the simulation estimates the reliability of the studied machines at a higher level. The simulation and white-box method sometimes provide exactly the same results, which are caused by their similar structure of analysis. On average, 9% of the data are missed in the white-box analysis due to a lack of sufficient data in some of the subsystems of the studies' rigs.

INTRODUCTION

During the last three decades different drilling techniques, from pneumatic to electro-hydraulic, have been developed. Nowadays, drilling rigs have high capacities and are equipped with different advanced monitoring and control systems. The focus of development in this machinery has not just been on speed, but also on the quality of drilling, operation costs, and safety[1]. Face drilling rigs are powerful machines, manufactured with a wide range of capabilities and are applied either in the mines or in construction projects. They are important machines with a critical role in the mine production rate and a construction project's duration. Therefore, their reliability and availability are very crucial for whole excavation operation. Collecting a wide range of data, getting the deep information from machine and well-established maintenance process are

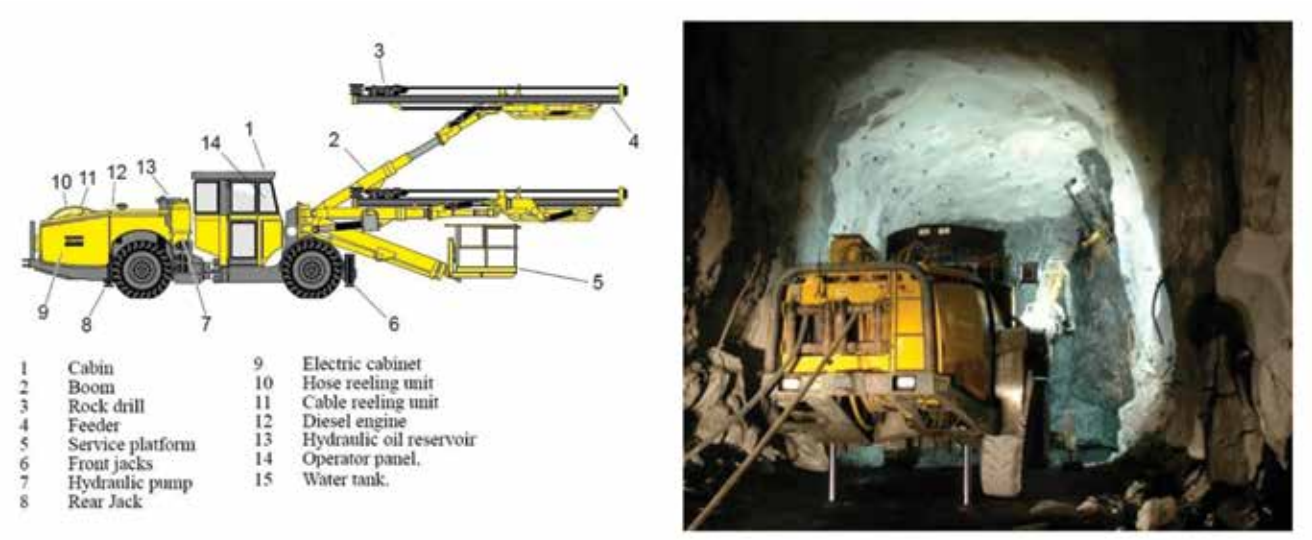


Figure 1: One of case study drilling rigs; (left) basic units [5]; (right) drilling rig in mine[6].

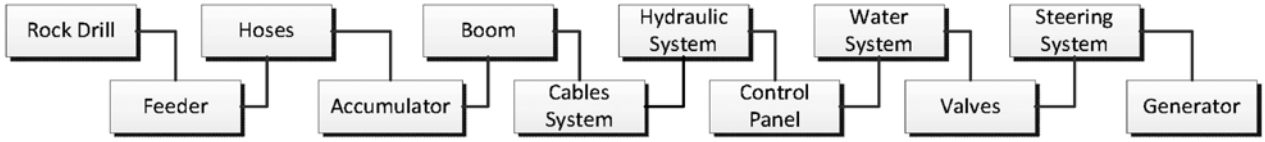


Figure 2: The defined reliability block diagram for face drilling rig.

required to achieve a reliable drilling operation. Drilling machines are complex and compactly designed, making their maintenance challenging, which suggests the need for an in-depth study of their failure behavior[2]. Reliability studies in underground mining machinery have been carried out by many researchers and in different types of mines, varying from coal to hard rock metal mines. A review of the related outstanding literature has been presented by Hoseinie *et al.*[3]. It has been emphasised in the past that reliability studies in mines, specifically in underground mining, are particularly difficult due to their harsh operation and maintenance environment, as well as work pressures[4]. Considering the importance of mobile underground machinery for mine production, the complexity of the machinery and the harsh mining environment, a reliability analysis of the drilling rig must meet rigorous requirements and come up with clear results.

In this paper, the reliability of a fleet of face drilling rigs in a Swedish mine is analysed using three different approaches: two analytical methods (white-box and black-box modeling) and simulation. Finally, the results of each approach are discussed and compered.

FACE DRILLING RIGS: A CASE STUDY

Face drilling rigs are used for the drilling of blasting holes in construction and mining tunnels/galleries. Many international companies manufacture drilling rigs that are composed of similar operational units and have similar structures, however, they have variable technical characteristics, especially in capacity and power. This study examined a fleet of three rigs, called Machine A, B, and C in a Swedish underground metal mine. All of the rigs in this study are the same model and are manufactured by the Atlas Copco Company. Each rig has four retractable stabiliser legs and an articulated four-wheel drive chassis. They are operated electrically by a maximum power capacity of 158 kW. Figure 1 shows the schematic view of the studied rigs and their different parts. According to the operation manuals, field observations, and maintenance reports from the case study mine, the drilling rig is considered a system that consists of 12 operational subsystems working simultaneously to achieve the desired function and is connected in a series of configuration, as shown in **Figure 2**.

Data Collection

The required data for this study was collected from available operation and maintenance reports extracted from a computerised maintenance management system (CMMS) called “MAXIMO” and some field observations over a period of two years. After refining and filtering the data, the failures of each subsystem were assigned to its data-log and the failure frequency was analysed. As can be seen in **Figure 3**, the Pareto analysis shows that hoses, rock, drills and feeders are the top three subsystems/units view point of failure frequency. On average, 63.3% of all recorded failures in this

Fleet are related to these subsystems. All of the defined subsystems for the face drilling rigs do not appear in the Pareto analysis in all machines. This means that some subsystems had no failures during the study period or had fewer than five failures and were not analysed (the figure’s “others” column represents these subsystems).

Reliability Analysis

Collecting data, analyzing, and making a decision are time consuming processes that must be done during any reliability study. In general, there are three main approaches for the reliability analysis of the systems[7,8];

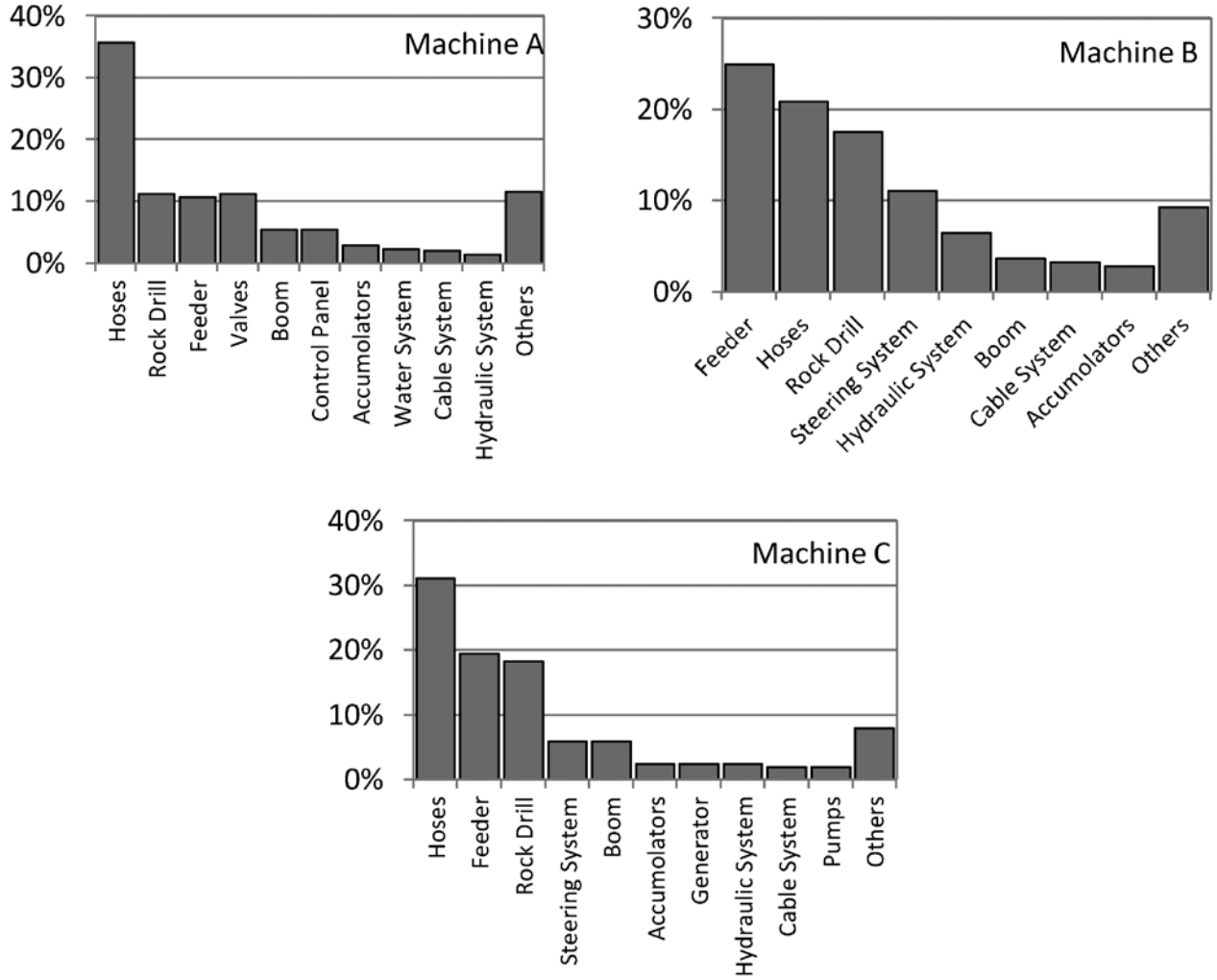


Figure 3: Pareto analysis on studied face drilling rigs.

(a) White-box modeling: the white-box (or structural) approach explicitly takes the structure of the system into account[9,10]. In other words, in this method, the state of the system is modeled in terms of the states of the various components[8]. In order to model the reliability of the system, the reliability of all subsystems are calculated and combined based on the reliability network and overall system configuration.

(b) Black-box modeling: black-box analysis is a system-based analytical method, referring to the technique of testing a system with no knowledge of its internal workings[11]. When the system is treated as a black-box, there is no concern about how the system "looks inside"[12]. In this approach, the system is described either in terms of two states (working/failed) or more than two states (allowing for one or more partially failed states) without explicitly linking them to components of the system[8].

(c) Simulation: stochastic simulation is a suitable technique to assess the reliability of a system and can be applied in two ways[8,9,12]: (1) Sequential approach: by examining each basic interval of the simulated period in chronological order; and (2) Random approach: by examining randomly chosen basic intervals of the system lifetime.

The random approach, usually known as the "Monte Carlo" method, is a numerical method that allows for the solution to mathematical and technical problems by means of a system of probabilistic

models and the simulation of random variables. In this method the stochastic failure occurrence of the system is analysed and the probability of the failure and success of the system operation are calculated. The failure behavior of each subsystem is considered in this method.

Every mentioned reliability analysis approach has special and different inputs, advantages, disadvantages, limitations and outputs. Sometimes when the white-box approach is applied there are some statistical-based restrictions. For example, it is very difficult to fit a failure density function on the available data in subsystems that have less than five numbers of failures[13]. Therefore, all these failures are missed in the calculations and analysis. However, they actually exist. In the black-box approach the all of the failure data is put in one set. The main disadvantage of this method is that we are not able to study the failure behavior of each subsystem and detailed information about the failure modes of the system is missed. As for its advantages, the calculation time is very low and the complete failure data is used in this approach. The simulation method stands in line

with white-box modeling, nevertheless, the final reliability analysis of the whole system is performed stochastically. The main disadvantages of this method include high calculation time and missing failure data during the distribution fitting.

Within this article, the available failure data is analysed by the above mentioned methods and the resulting reliability plots and the applications of each approach are compared and discussed.

Reliability analysis using the white-box modeling approach

As discussed, in the white-box method the reliability of the whole machine is calculated based on the reliability of its subsystems. Therefore, all of the data analysis is performed during the time between failures (TBF) of the subsystems. Since the subsystems of a face drilling rig have a series of configurations, the reliability of the whole machine in time t is calculated by multiplying the reliability of all subsystems at time *t*.

Table 1: Failure data analysis of subsystems of studied machines.

Subsystems	Best fitted function		
	Machine A	Machine B	Machine C
Hoses	Weibull 2P α = 0.92, β = 20.75	Weibull 3P α = 0.95, β = 55.53, γ = 0.6	Lognormal 3P σ = 1.07, μ = 3.12, γ = −1.19
K-S goodness of fit	0.067	0.121	0.094
Rock Drill	Weibull 2P α = 0.98, β = 69.1	Lognormal σ = 1.26, μ = 3,27	Gamma 3P α = 1.13, β = 52.61
K-S goodness of fit	0.115	0.084	0.173
Feeder	Lognormal 3P σ = 1.26, μ = 3.4, γ = −0.14	Weibull 2P α = 0.82, β = 42.47	Exponential λ = 0.018
K-S goodness of fit	0.089	0.115	0.109
Boom	Weibull 2P α = 1.04, β = 146.28	Exponential λ = 0.006	Weibull 3P α = 0.58, β = 122.7, γ = 19.04
K-S goodness of fit	0.023	0.159	0.063
Accumulators	Normal σ = 197.41, μ = 256.16	Normal σ = 214.1, μ = 300.5	Weibull 2P α = 1.48, β = 502.1
K-S goodness of fit	0.095	0.118	0.159
Cable System	Less than 5 failures	Weibull 2P α = 1.09, β = 339.7	Exponential λ = 0.002
K-S goodness of fit		0.039	0.047
Hydraulic System	Gamma α = 0,336, β = 1047	Weibull 3P α = 0.6, β = 148.3, γ = 16.92	Lognormal 3P σ = 0.77, μ = 5.45, γ = −66.72
K-S goodness of fit	0.152	0.089	0.096
Valves	Lognormal σ = 1.17, μ = 4.36	Less than 5 failures	Less than 5 failures
K-S goodness of fit	0.117		
Control Panel	Exponential λ = 0.008	Less than 5 failures	Less than 5 failures
K-S goodness of fit	0.053		
Water System	Lognormal σ = 1.27, μ = 5.17	Less than 5 failures	Less than 5 failures
K-S goodness of fit	0.071		
Steering System	Less than 5 failures	Weibull 3P α = 1.15, β = 112.9, γ = 4.27	Lognormal 3P σ = 0.62, μ = 5.22, γ = −37.7
K-S goodness of fit		0.108	0.113
Generator	Less than 5 failures	Less than 5 failures	Weibull 2P α = 0.999, β = 299.82
K-S goodness of fit			0.021
Total number of failures	313	196	231

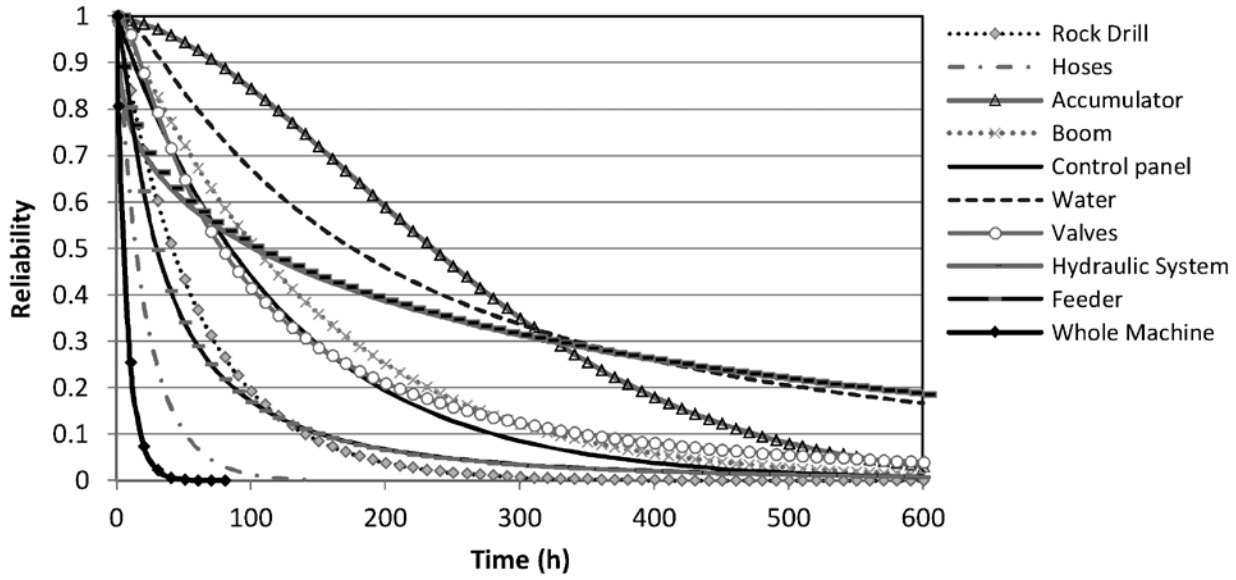


Figure 4: Reliability plots of the subsystems of Machine A using white-box approach.

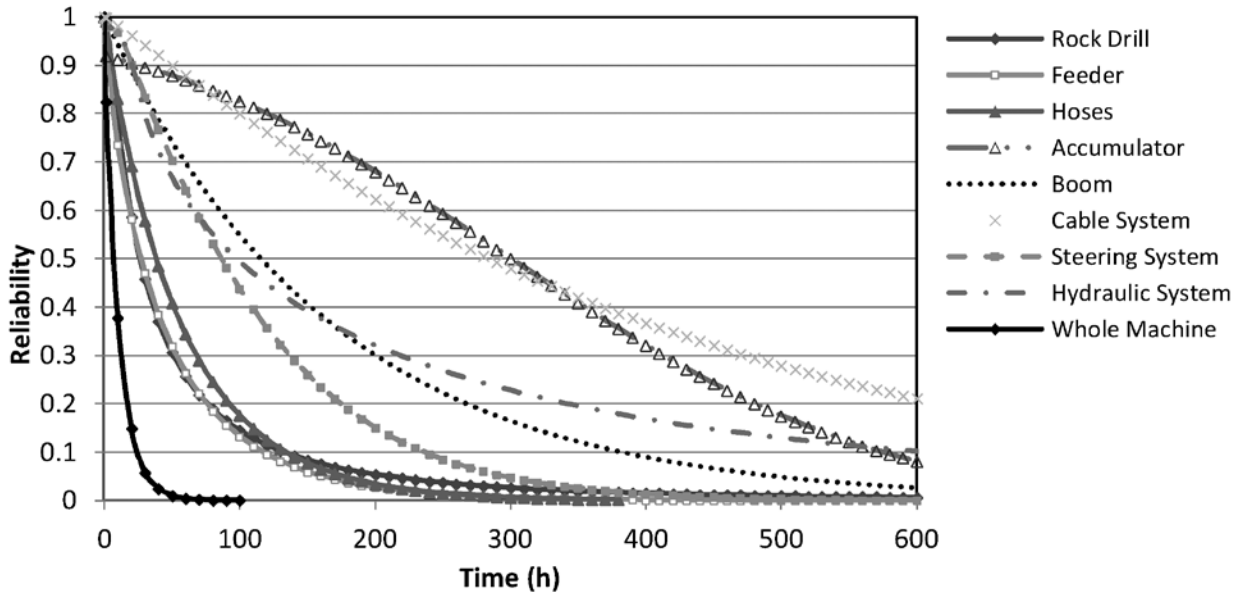


Figure 5: Reliability plots of the subsystems of Machine B using white-box approach.

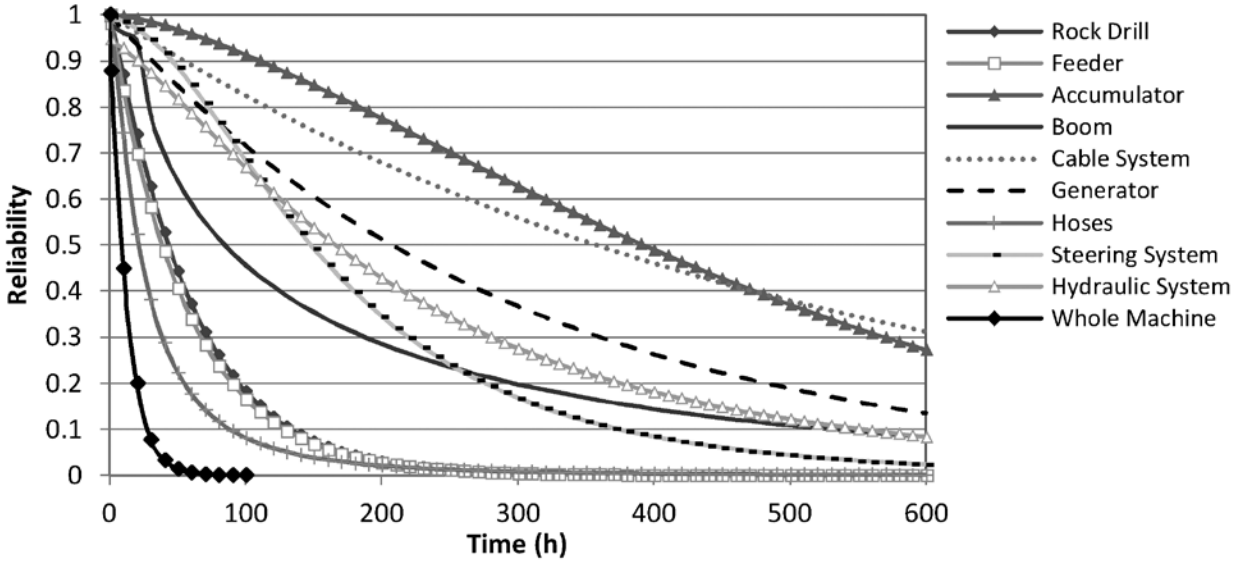


Figure 6: Reliability plots of the subsystems of Machine C using white-box approach.

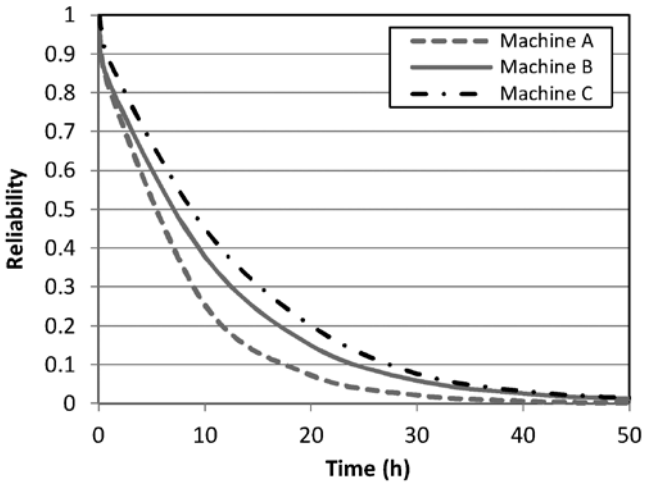


Figure 7: Reliability plots of all machines using white-box modeling.

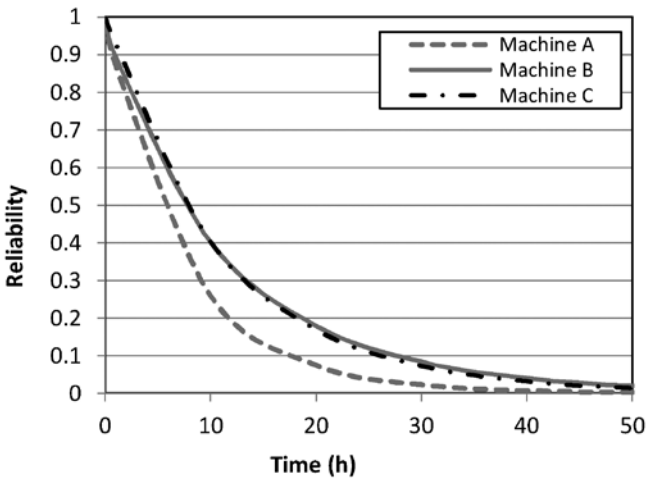


Figure 8: Reliability plots of all studied machines using black-box modeling.

In the CMMS, the failure data are recorded based on calendar time. Since drilling is not a continuous process, the TBFs were estimated by considering the utilization of each rig. Reliability and maintainability data analysis is usually done based on the assumption that the TBF and TTR data are independent and identically distributed (iid) in the time domain. It was critical to conduct a formal verification analysis of the assumption, otherwise, completely wrong conclusions could be drawn[14,15]. In this study, statistical analysis could not find trends in the failure and repair data. The failure data were tested for trends with the Laplace trend test, which is used to determine whether a data set is identically distributed or not[14]. If such a trend is observed, classical statistical techniques for reliability analysis may not be appropriate, and a non-stationary model such as the non-homogenous Poisson process (NHPP) must be fitted[15,16]. Otherwise, the serial correlation test can be used to test the dependence of the failure data. A dependence test determines whether successive failures are dependent in data without a long-term trend or not[15]. If dependence is not observed, the iid assumption is valid.

In this study, after testing and confirming the validity of the iid assumption, different types of statistical distributions were examined on the data and their parameters were estimated using Easyfit Professional software version 5.6[17] and Minitab software[18]. The goodness of a fit of the distributions was tested by using the Kolmogorov-Smirnov (K-S) test. All of the statistical tests used a significance level of 0.05. The best fitted failure density functions are presented in **Table 1**.

The reliability plots of the subsystems of the studied machines and the reliability of the whole machines based on the white-box modeling are presented in **Figures 4-6**. As can be seen in these figures, the accumulator, cable, water, and generator subsystems have the highest reliability, while the feeder and hose subsystems have the lowest reliability level. The figures show that the reliability behaviors of the all subsystems are more or less similar in all studied machines, possibly because they are all in the same working environment, are the same model, come from the same manufacturer, have the same maintenance crew, and are used by operators with similar skills.

Figure 7 shows the reliability plots of all three machines using the white-box method in one area. As the figure indicates, machine C has the highest reliability among the studied machines, while machine A has the lowest level. The maximum difference value is 20% at almost 15 h. An obvious result of these plots is that the studied machines are almost equal in reliability during the period of high reliability operation (from time 0 to 5 h) and also during the period of very low reliability (after 35 h). The reliability of all machines decreases to almost zero after 50 h of operation.

Reliability analysis using black-box modelling approach

In this approach, no subsystems were considered for the machines and all of the failure data were analysed as one statistical population per one machine. The iid testing procedures and data analysis were performed on the whole failure data of each machine. Reliability models

Table 2: Parameters of best-fitted distributions on failure data using the black-box approach.

Machine	Number of Failures	Best-Fitted Function	Parameters
A	347	Weibull (3P)	α = 0.93 β = 7.11 γ = 0.11
B	216	Weibull (2P)	α = 0.91 β = 11.04
C	251	Weibull (3P)	α = 0.94 β = 10.69 γ = 0.33

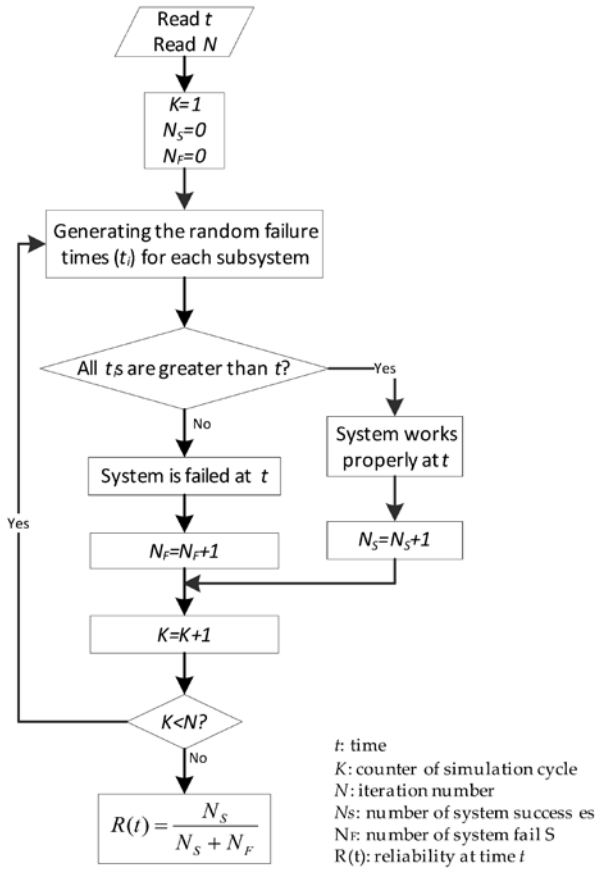


Figure 9: The flowchart of the K–R Monte Carlo reliability simulation method (adopted from[25]).

and calculated plots are drawn from these data. The results of the data analysis using the black-box method are presented in **Table 2**.

Using the parameters of the best-fit functions given in **Table 2**, the reliability plots of the machines are drawn in **Figure 8**. As shown in this figure, the reliability of all the machines reaches almost zero after 50 h of operation. The reliability of machine A is the lowest. In total, the black-box method finds very close, almost similar values for machines B and C.

Reliability Analysis Using Simulation Approach

The Monte Carlo simulation is a powerful approach for the reliability analysis of large-scale complex networks that has been developed in several stages and different application guidelines have been recommended so far. During the simulation process, subsystems may have random failures and repair distributions, and failure data of the subsystems are sometimes not sufficient and smaller in sample size[19]. These two phenomena cause some challenges in the simulation, nevertheless, they have not been able to restrict the applications or reduce its profit.

According to the available literature, the Monte Carlo reliability simulation is carried out by different algorithms that are mainly built up on the Kamat and Raily (K–M)[20] algorithm. It is considered the most general reliability simulation method, and other methods, such as Rice

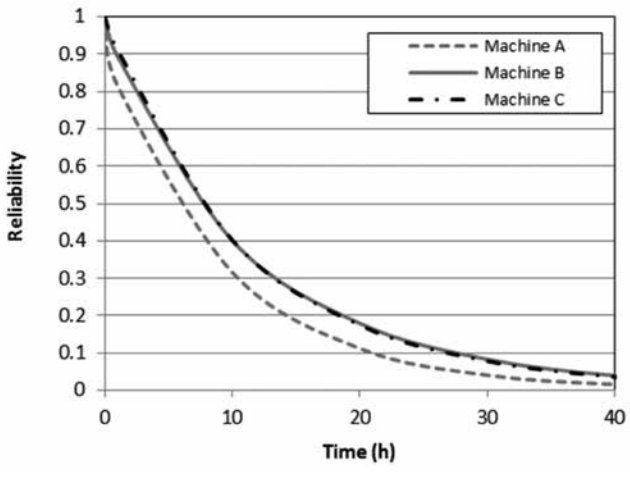


Figure 10: Reliability plots of all three studied machines achieved from the simulation method.

and Moore (R–M)[21], Chao and Huang (C–H)[22], Lin *et al*. (L–D–L)[23], and Lin and Donagh (L–D)[24] are known as the modifications or specializations of this method[25]. Therefore, in this paper the K–R method is applied for the reliability simulation of face drilling rigs.

In the Kamat and Raily method the random failure times for each subsystem are generated based on defined failure distribution functions, which are then applied to assess the success or the failure of the system. **Figure 9** presents the flowchart of the K–M simulation method. More details of this method are presented by Wang and Pham[19] and Hoseinie *et al*.[25,26].

According to the presented algorithm in **Figure 9**, a computer code was developed in MATLAB software. For each machine, the program was run in different operation times and with the iteration number of 10,000. The simulated reliability plots of the studied machines are presented in **Figure 10**. As can be seen in this figure, the reliability of Machine A is the lowest value as well as in the other two methods. Also, the difference between the reliability of Machine B and C are a maximum 10%.

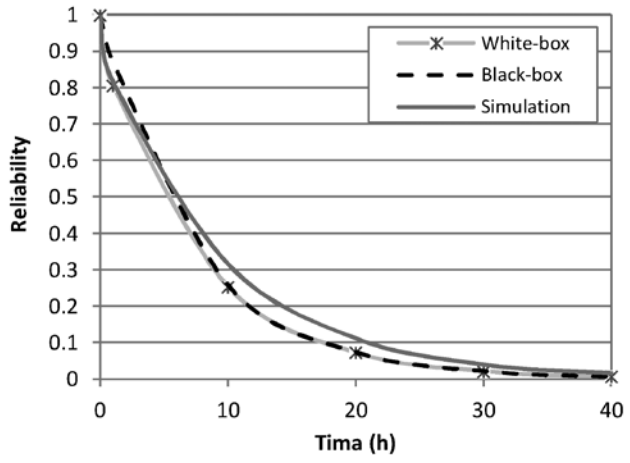


Figure 11: Reliability plots of machine A resulted from the different modeling approaches.

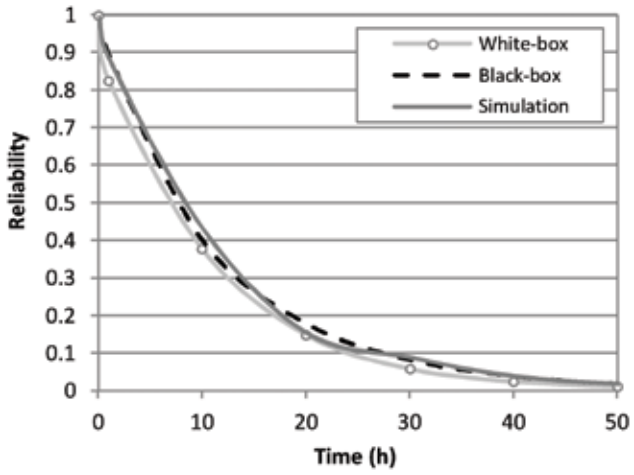


Figure 12: Reliability plots of machine B resulted from the different modeling approaches.

COMPARISON AND DISCUSSION

As discussed earlier, the reliabilities of the face drilling rigs were analysed using three methods and the resulted reliability plots for each machine are presented in **Figures 11-13**. As seen in these figures, the resulted reliability plots are very similar and sometimes have the same values in each machine.

In Machine A (**Figure 11**), during the initial eight hours, the results of all methods are very similar to each other. After this period, the reliability plots of the white-box and black-box modeling become almost the same, but the simulation plot comes over them. At the end, after 30 h of operation, the reliability plots of all the methods show almost the same values. Finally, all reach zero after 40 h.

In Machine B (**Figure 12**), the reliability plot of simulation is almost the same values as the black-box modeling. Both of them are higher than the white-box approach. In total, the reliability of this machine reaches almost zero after 50 h, which is 10 h more than Machine A.

In Machine C (**Figure 13**), the results are complicated. Before 5 h, the simulation plot is close to the black-box

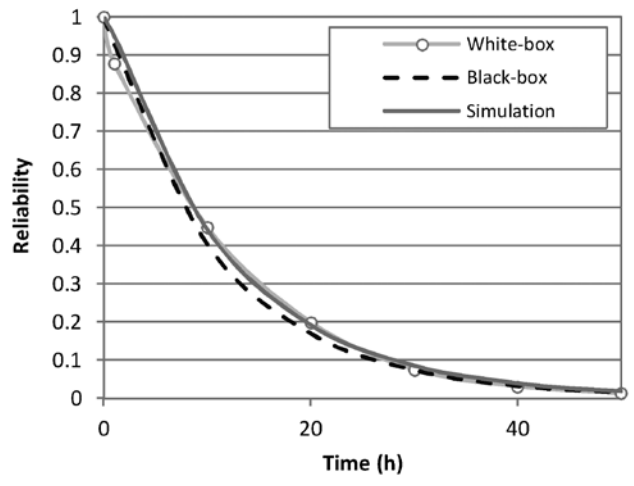


Figure 13: Reliability plots of machine C resulted from of different modeling approaches.

Table 3: Number of analysed and missed data view point of different modeling approaches.

Machine	Number of failures	Used in analysis	Missed failure data (%)
	Black-box	White-box	
A	347	313	9.8
B	216	196	9.3
C	251	231	8

method and is higher than the white-box. After 5 h, the simulation result separates from the black-box and is closer to the white-box. In passing 25 h, all plots show the same values and they join each other.

In general, the simulation method determines the higher values with greater accuracy than the other methods or are very similar in reliability values to the white-box method. It is caused by the process of simulation method, which is based on the failure distribution functions of the machines' subsystems.

In more or less the whole time period in all of the studied machines, the black-box and white-box methods reveal a reasonable difference in values (except at times after 10 h in machine A). Because

when the white-box method is used, the frequencies of the failures in some of the subsystems are less than five and therefore, the related subsystems and their failures are eliminated from the analysis process. Nevertheless, in the black-box approach all of the failures are counted and the analysis is performed using a complete set of failure data. In detail, according to **Tables 1** and **2**, the number of missing data can be summarised as shown in **Table 3**. On average, 9.3% of the data has been missed within the white-box analysis, which accounts for the differences in the resulted values of this method. However, even without considering the missed data, the combination of different failure modes and failure distributions in the black-box method results in a different description of system reliability, which presents a holistic and general view of system reliability.

In other view, according to **Figures 7-9**, the ranking of the studied machines in the white-box method is different with the other two methods. In the white-box (**Figure 7**), the reliability of machine C is obviously higher than machine B and A, nevertheless, in the black-box and simulation approaches the reliability of machine C and B are almost the same values. The reliability of machine A is the lowest value in all methods.

Finally, according to the presented results, it could be concluded that, even though the results of the three mentioned reliability analysis methods are clearly different, this is sometimes negligible. Therefore, in fleet level analysis, considering the required time for analysis the black-box method could be helpful in finding the reliability of each machine or detecting the weakest machine (lowest reliability) in the fleet. In further analysis, the white-box method can be used, but only on the weakest machine to do the subsystem and component level analysis.

Since the working environment is so harsh in mining, the machinery must be analysed and the reliability view point monitored in regular time periods. Therefore, considering the time consuming nature of the simulation method, it is not suggested that it be applied in normal mining machineries.

CONCLUSIONS

In this paper the reliability of face drilling machines in a Swedish underground mine were analysed using white-box, black-box, and simulation methods. The overall findings could be listed as followings:

1. Applied reliability analysis methods obviously reveal different results, where the difference varies from almost zero to 20%. It is recommended to apply the black-box method in fleet level analysis, the white-box in machine level and simulation only in complex systems or in the case of a lack of available failure data.

2. Comparative analysis shows that the applied reliability analysis approaches present different rankings of machines within the fleet, nevertheless, in finding the last-ranked machine they present the same result.

3. According to all findings of this study, when our aim is to analyse the machine's reliability itself and to investigate the production stoppages and production reliability, the black-box method is the best method of modeling. All failure data are included in this method, and it is the shortest and easiest way when compared to the other methods.

ACKNOWLEDGMENTS

The authors are grateful to the employees and managers of Boliden Mineral AB for their kind cooperation during the data collection. The financial support of the Center of Advanced Mining and Metallurgy (CAAM) of Lulea University of Technology is also acknowledged.

AUTHOR CONTRIBUTIONS

Study conception and design were carried out by all authors (A, B, C); B collected the data; A, B and C analysed the data; A made the simulations; A, B, C wrote the article.

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Digital look over the shoulder

The user is guided through the commissioning process from the back office.

Thanks to digitalisation, it is no longer unusual to parametise and commission single components remotely. BEUMER Group thinks ahead and, for the first time, commissions a complete packaging line including palletiser – from a distance of over 4,000 kilometres.

Helping customers in the event of faults or shutdowns of existing systems is no problem for BEUMER Group – even from a distance. The system provider was confronted with a completely new situation when a planned commissioning, which involves the dispatch of service personnel to the site, could not be carried out due to travel restrictions caused by the COVID-19 pandemic. BEUMER Group was flexible and set the course for "remote commissioning" – commissioning from a distance.

"The trigger was clearly the pandemic," explains Peter Teichrib, a department manager in Engineering at BEUMER Group. However, this is not the only scenario that requires BEUMER's new service remote commissioning. Everything that makes personal access to systems and users difficult or impossible requires new solutions.

As a concrete example, Teichrib mentions the packaging line of the cement manufacturer Norm LLC in Azerbaijan, which was almost completely erected on site. This line consists of two bag transport systems, the layer palletiser BEUMER paletpac 5000 and the BEUMER stretch hood A packaging line. "All components were already completely installed. Only some electrical installations and commissioning still had to be carried out when our experts had to leave the country due to the worldwide

The project comprises two bag transport systems, the layer palletiser BEUMER paletpac 5000 and the BEUMER stretch hood A packaging system.

On site: BEUMER Smart Glasses, smartphone and laptop provide an audiovisual connection to BEUMER Group.

travel warning". A delicate situation for the customer who has already included the capacity of the new packaging line in his calculations. If the line does not start up, the customer faces the thread of delivery bottlenecks and loss of market share.

TEST RUN REQUIRED

BEUMER Group decided to launch remote commissioning as a pilot project. "The conditions were exceptionally good, which certainly cannot be taken for granted," emphasises Teichrib. In general, a number of conditions must be met before the "remote commissioning" project can even be considered. The system must be tested in-house in advance. "With this system, we had indeed carried out an extended in-house commissioning, as the BEUMER paletpac 5000 was running with the new PLC S7-1500 for the first time," says the department manager. "We wanted to make sure that everything would work perfectly later. Finally, it was this circumstance that made remote commissioning possible in the first place." BEUMER Group also recommends to supply the BEUMER stretch hood with the film tested in advance. This way, possible differences in film quality can be excluded as a source of problems during commissioning.

KNOW HOW MEETS TECHNOLOGY

In general the customer needs qualified maintenance and operating personnel who is preferably familiar with BEUMER systems. This is another prerequisite for successful remote commissioning. On the hardware side, several IP cameras provide the necessary overview of the complete system, while BEUMER Smart Glasses, specially developed data glasses, connect the BEUMER experts audiovisually to the user on site. "A broadband Internet connection is, of course, required," says Teichrib. The data glasses allow a detailed view: The BEUMER Customer Support sees the same thing as the wearer on site and can directly specify the correct actions to be taken. In this way, the user is guided step by step through the commissioning process.

The cameras and BEUMER Smart Glasses are part of the plug-and-play set for remote commissioning. This also includes a WLAN router for the BEUMER Smart Glasses and a VPN client installed on an mGuard router. The IP cameras must be connected via LAN cable to ensure sufficient image quality and stable transmission. "First, we installed the hardware and software components in our factory and tested the configuration. The complete package has been shipped to Norm LLC," says Teichrib. This procedure has proven itself and is also planned for future remote commissioning projects.

KEEPING THE OVERVIEW

BEUMER Group set up a separate back office for this project at short notice: Using four monitors and a laptop,

Twenty percent of the electrical installation were carried out by the customer itself – the BEUMER Customer Support checked and directed all steps from a distance using the BEUMER Smart Glasses.

Never change a running system: BEUMER Group recommends to supply the BEUMER stretch hood A with the previously tested film to ensure a smooth start of the remote commissioning.

the service staff always had an overview of the images from the IP cameras, the field of view of the BEUMER Smart Glasses and the data of the system sent via the VPN client.

"Broadband Internet access, technology and know-how – at Norm LLC we encountered ideal conditions, which we made the best possible use of," explains the department manager. "Within a very short time we were able to develop a concept that will guide us safely and reliably through future remote commissioning projects. Standardised processes enable us to eliminate sources of error and offer our customers a reliable service – quickly and flexibly."

Regardless of external circumstances: If BEUMER Group digitally takes the users by the hand via "remote commissioning", the understanding and know-how of the systems grow. This motivates the customer's personnel on site, a fact from which the user benefits as much as BEUMER Group – a better understanding of the system will significantly simplify future remote maintenance and services.

The remote commissioning of the packaging line at Norm LLC has shown that with adequate framework conditions, such as well-trained maintenance personnel and technically high-quality IT equipment, new ground can be broken. BEUMER Group's technology and competence have impressively confirmed this.

Photo credits: BEUMER Group GmbH & Co. KG

The invisible enemy

HOW OZONE AND ULTRA VIOLET DRAMATICALLY SHORTENS THE WORKING LIFE OF CONVEYOR BELTS

There are many things that determine the working lifetime of conveyor belts. The incessant abrasive action of the materials being conveyed; the impact of heavy, sharp lumps of rock being dropped onto them and the ripping and tearing caused when rocks or foreign objects become trapped. All of these factors are, of course, common knowledge to operators of conveyors. As I have talked about previously in Mining & Quarry World, conveyor belts can be engineered to significantly limit the amount of damage these factors can cause.

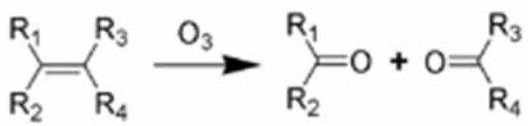
However, what is definitely *not* common knowledge is that there are also two other 'invisible' and inescapable factors that have a huge influence on the operational lifetime of a rubber conveyor belt. Those factors are ozone (O_3) and ultraviolet light (UV) and, contrary to often common misconceptions, the damage they cause is not limited to only higher altitudes or particularly sunny climates. Far from it in fact.

FROM PROTECTOR TO DESTROYER

Ozone (O_3) occurs naturally in the upper atmosphere. It is formed continuously by the action of solar ultraviolet radiation on molecular oxygen (O_2). At high altitude, ozone acts as a protective shield by absorbing harmful ultraviolet rays. Wind currents carry O_3 to the atmosphere at the Earth's surface. At low altitude, ozone becomes a pollutant. Ground level or "bad" ozone is not emitted directly into the air, but is created by the photolysis of nitrogen dioxide (NO_2) from automobile exhaust and industrial discharges. This is known as ozonolysis.

OZONOLYSIS

Ozonolysis is the reaction that occurs between the molecular structure (double bonds) and ozone:



Ozone cracks in the surface of the rubber.

Foolish to underestimate the damage caused by UV exposure.

The scientific explanation is that the immediate result is formation of an ozonide, which then decomposes rapidly so that the double bond molecule is split. The critical step in the breakdown of molecular chains is when polymers are attacked. The strength of polymers depends on the chain molecular weight or degree of polymerization. The longer the chain length, the greater the mechanical strengths including the highly important tensile strength of the rubber. By splitting the chain, the molecular weight drops rapidly. There comes a point when very little strength remains and cracks starts to form. Further attacks occur inside the freshly exposed cracks, which continue to grow steadily until they complete a 'circuit' and the product separates or fails.

Even tiny traces of ozone in the air will attack the molecular structure of rubber. It increases the acidity of carbon black surfaces with natural rubber, polybutadiene, styrene-butadiene rubber and nitrile rubber being the most sensitive to degradation. The first visible sign is when cracks start to appear in the surface of the rubber.

Although the variability of weather, airflow patterns, seasonal changes, the level of emissions and climatic conditions do mean that ozone concentrations can differ from one location to another, the fact is that ground level ozone pollution is ever-present and its effects should therefore never be under-estimated.

A PARTNER IN CRIME

To make matters worse, 'bad' ozone has a partner in crime that also has a seriously detrimental effect on rubber. Ultraviolet light from sunlight and fluorescent lighting accelerates rubber deterioration because it produces photochemical reactions that promote the oxidation of the rubber surface resulting in a loss in mechanical strength. This is known as 'UV degradation'.

Ironically, the rapid decline in the ozone layer in the upper atmosphere over the past several decades is allowing an increasing level of UV radiation to reach the earth's surface. Continuous exposure is a more serious problem than intermittent exposure, since attack is dependent on the extent and duration of the exposure. As you would expect, the problem is worse in sunnier, hot climates

Transversal cracks deepen under the repeated stress of passing over the pulleys and drums.

Dunlop's ozone testing cabinet.

Samples are checked for cracking at two-hourly intervals.

Some rubber literally disintegrates.

but even in the most moderate of environments, the problem is ever-present and, as with ozone, it would be foolish to underestimate the damage it causes.

HIDDEN EFFECTS

Ozone cracks form in rubber that is under tension. However, the critical strain needed is only very small. Even a belt that has not yet been fitted on a conveyor has a certain amount of intrinsic tension. The cracks are always oriented at right angles to the strain axis. The dynamic stress that a conveyor belt undergoes while in operation is considerable. Ozone attack occurs at the points where the strain is greatest.

The repeated action of the mechanical stress of the conveyor belt and the frictional process from the idler means that the rubber molecular chain will break to form what scientists refer to as a 'free radical'. This triggers the oxidative chain reaction that forms a chemical process, which mechanically breaks the molecular chain and activates the oxidation process. Who would have ever believed that rubber conveyor belts could be so scientifically complex? They are certainly not just the giant black rubber bands that so many people seem to think they are!

STRESS MAGNIFICATION

At first glance, having small cracks in the surface rubber may not seem to be a big problem but over a period of time the rubber becomes increasingly brittle. As I have just mentioned, transversal cracks deepen under the repeated stress of passing over the pulleys and drums. The ozone continues to attack so the cracks will steadily grow until catastrophic failure occurs. Cracks often present other potential risks such as scrapers catching on them and tearing off parts of the cover. Re-splicing can also become increasingly difficult over time as the adhesion properties of the rubber diminish.

Yet another 'hidden' problem is that moisture seeps into the cracks. This then penetrates down to the actual carcass of the belt. In multi-ply belts, the fibres of the weft strands of the plies expand as they absorb moisture, which in turn causes sections of the carcass to contract (shorten) as the weft strands pull on the warp strands of the ply. This can result in tracking problems, which can be difficult to pinpoint, and which no amount of steering idler adjustment can compensate for. Last but not least, there can also be significant environmental and health and safety consequences because fine particles of dust penetrate the cracks and are then discharged (shaken out) on the return (underside) run of the belt.

ENTIRELY PREVENTABLE

Fortunately, damage caused by ozone and ultraviolet is almost entirely preventable thanks to the use of modern technology. Several years ago, we at Dunlop were among the very first in the world to make use of new technology that enabled the effects of ozone to be tested and measured. We equipped our laboratory in Drachten in The Netherlands with the very latest ozone testing equipment and introduced mandatory testing to EN/ISO 1431 international standards for all Dunlop rubber products. The same testing regime was applied to samples of belts made by other manufacturers.

Ground level ozone seriously damages rubber

As a direct result, special anti-oxidant additives that act as highly efficient anti-ozonants and protect against the damaging effects of ozone and ultra violet became an essential ingredient in all Dunlop rubber compound recipes without exception. Unfortunately, for their customers, hardly any other belt manufacturers make use of these anti-oxidant additives. I will explain the reason for this shortly.

EN/ISO 1431 TESTING

To scientifically measure resistance to ozone in accordance with the EN/ISO 1431 test method, samples are placed under tension (eg. 20% elongation) inside an ozone testing cabinet and exposed to highly concentrated levels of ozone for a period of up to 96 hours (@ 40°C, 50 pphm and 20% strain).

Samples are closely examined for evidence of cracking at two-hourly intervals and the results carefully measured and recorded. Experience has determined that in order for the rubber to be regarded as adequately resistant, the pass criteria needs to be that the rubber sample does not show any signs of cracking within the 96-hour period.

SWEPT UNDER THE CARPET

Despite its crucial importance, in my experience, ozone and UV resistance is very rarely, if ever, mentioned by belt manufacturers and suppliers. It is a subject that is, as they say, swept under the carpet. This is almost certainly because so much of the market is dominated by those trying to undercut their competitors on price. Anti-ozonant additives are not cheap and are therefore not used in the pursuit of a price advantage. I would also argue that for many belt suppliers, anything that prolongs the working life of belts is not particularly good for business.

We have hardly ever tested a competitor's belt (and never non-European import belt in my experience) that has survived the EN/ISO 1431 specific test conditions without cracking. In the majority of cases the cracks start to appear within 6 to 8 hours rather than the target of 96 hours. Sadly, it is not an uncommon sight to see rubber samples completely disintegrate within a matter of a few hours. Typical 40 and 60 Shore sheeting and skirting rubber seems to be even worse.

Because of the sheer size of industrial conveyor belts, it is common practice amongst manufacturers and distributors to store rolls of belting in the open-air. Belts can often be held in stock for long periods, sometimes for several years, before they are eventually dispatched and ultimately put to use. During that time, they are vulnerable to the ever-present effects of ozone and UV radiation. A number of conveyor belt users have reported that surface cracking could be seen at the time of delivery.

NO HIDING PLACE.

The importance of having conveyor belts that are resistant to ozone and ultra violet can no longer be ignored. Unless conveyor operators start insisting on having belts that are ozone & UV resistant then the vast majority of belt manufacturers and suppliers will continue to ignore the issue.

For all buyers of rubber conveyor belts there should be **two** absolute pre-requisites when choosing any type of belt. Firstly, regardless of type, the rubber covers should have good resistance to abrasive wear. Just as importantly, they need to be fully resistant to the effects of ozone and ultra violet. Without these essential properties the belt will not provide genuine value for money because it will need to be replaced far sooner than necessary. My advice is to always insist that the manufacturer/supplier provides certification confirming that the belt they are offering is fully resistant to ozone and UV in accordance with the EN/ISO 1431 test method.

Rob van Oijen

ABOUT THE AUTHOR

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

Orion paving way for another metals hub in Northern Cape

The copper strength of Orion Minerals is intensifying with recent announcements of the company's exclusive option to acquire the Okiep Copper Complex in South Africa's Northern Cape for A$7.5 million.

The Sydney- and Johannesburg-listed company, headed by Errol Smart, now has an opportunity to develop a second base metal production hub alongside its well-endowed first – the Prieska copper/zinc project, where it is intent on beneficiating copper in the province using renewable energy to produce green metal.

The combination of the Okiep Copper Complex and Prieska is seen by Orion Minerals as having the potential to transform it into a base metal's powerhouse.

The Okiep Copper Complex has an historical production of more than two-million tons of copper and it is seen as having outstanding exploration upside, particularly with the use of new technology.

In a presentation to investors and media, Smart drew attention to its similarity to Orion's well-infra-structured and data rich Prieska project, 450 km east of it. The area is also close to Vedanta's mines, mining services and contractors, as well as serviced mining towns.

The Okiep Copper Complex's mineral interests are held by three entities Orion has an option agreement to acquire. These are 56.25% of South African Tantalum Mining (SAFTA). The remaining 43.75% is held by South Africa's State-owned Industrial Development Corporation (IDC), which remains an active supporter and SAFTA financier. Orion and the IDC would cooperate to ensure compliance with the Mining Charter. The other two entities, of which 100% is targeted in each case, are Nababeeb Copper (NCC) and Bulletrap Copper (BCC).

Within 12 months of closing the proposed transaction, Orion is committed to spending a minimum of R4 million on exploration in each of the SAFTA, NCC and BCC areas.

These entities hold most of the large historical mines within the Okiep Copper Complex, for which there is technical data for 26 000 surface and underground drill holes and 150 000 technical reports, as well as several drilled orebodies with decline mine access and services are already in place.

All this is seen as potentially opening the way for production to commence in the next 18 months to 24 months, to supplement Prieska's production and expand Orion's base metals mining operations in the Northern Cape.

Ownership changes from Newmont to Gold Fields and Metorex, extending from the 1960s to 2019, have coincided with the ups and downs of the copper price cycles.

SAFTA has applied for a mining right on Metorex's last producing section, where production stopes at 150 m below surface remain open.

Between 1939 and 1993, 19 new deposits were discovered and mined, with regional exploration ceasing in 1993.

The transaction is seen by Orion as being a significant growth opportunity in a top-tier mining district, with a clear pathway to establishing the Northern Cape's second base metals production hub.

"We've got the team; we've got the people lined up. It is just that much easier to do it now," said Smart of the prospect of developing the Okiep Copper Complex with the Prieska project," was Smart's comment.

"I think we're in a long-term bull run for base metals in general, but for copper. The whole renewable energy and electrification drive globally is going to be a game changer. For the next decade, we are going to see extremely high prices," he said.

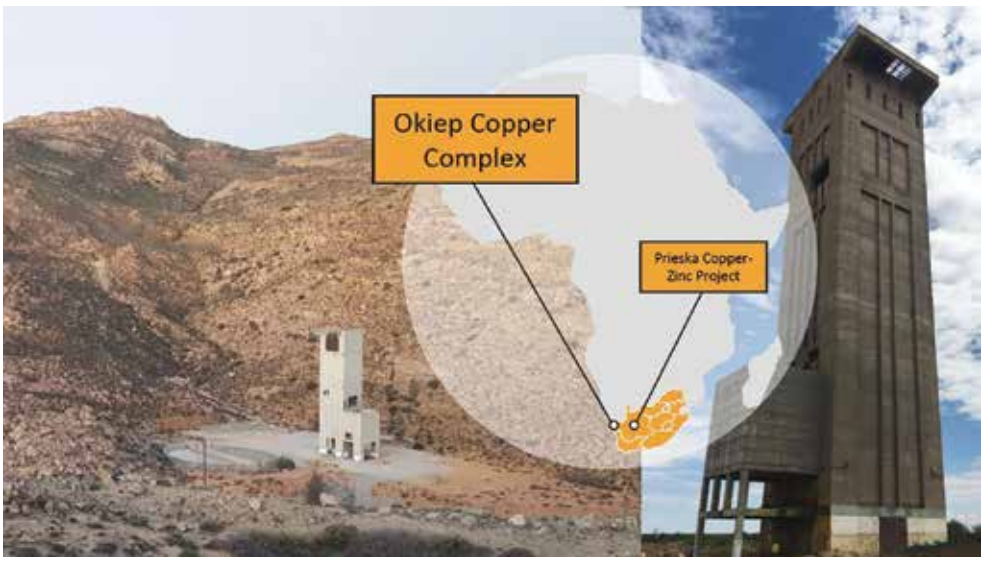
He added that funding for the Northern Cape projects by Orion were crystalising quite quickly.

"People are frustrated, and we're frustrated because it has taken longer than anybody would like. But it is a complex discussion and negotiation between all the parties because you have got to make sure that you have got the right group of financiers together, because otherwise your life just becomes hell afterwards.

"It's easy to grab quick money but you'll cry forever after. So, we would rather bide our time and do it right. We are getting very close to that and that is why we're comfortable to pull the trigger on this. We now know that Prieska is largely done and we can start turning our attention to the growth story.

On being committed to expending R4 million a year on exploration in each of the areas, he said: "That's a drop in the ocean for what should be spent on this property. If this were in Australia, they would be spending $20 million this year on projects like this. South Africa needs to get that kind of investment moving again and then we will have Australia-sized mines being built. Until we mobilise the money, that is not going to happen.

"The models are there. We just have to modify them a bit for our bespoke



purposes. We must not spend all our time trying to invent a wheel. It has been done, people know it is round and it has got rubber on it, so let us get on with it now.

"There'll be a lot of news flow in the next couple of weeks. We will probably put the scoping study out this quarter still possibly and we think that we can see a lot more than can go into Jorc-compliance very quickly. That is certainly the expectation. Anyone who hasn't been hiding under a rock will know that Peter Major has been walking around telling everybody there's 29 million tons of resources that were in Gold Fields resources statements that haven't been mined by Metorex," said Smart.

Major, of Mining of Mergence Corporate Solutions, is a veteran mining engineer, fund manager and analyst, who is highly regarded and well known in the mining and financial service industries. He frequently comments in the broadcast and print media as a mining investment authority.

"Everybody knows in South Africa that that's what the target is. I think he may be right, and I think apart from what was already Gold Fields' resource inventory, there is a helluva lot more to come. I don't think they've scratched the surface of this place," he said.

Investors are seeing that Orion has managed to achieve what no other junior resource company has in South Africa, particularly in terms of base metals.

"The IDC and we are very aligned in wanting to see beneficiation of copper in the Northern Cape using renewable energy to produce green metal. Those are our combined objectives, and, in this case, we are moving closer to them and let us hope we get them to the point where they become partners in Prieska shortly as well. If we do the same in Springbok as what we are doing in Prieska, it will be good for South Africa,"

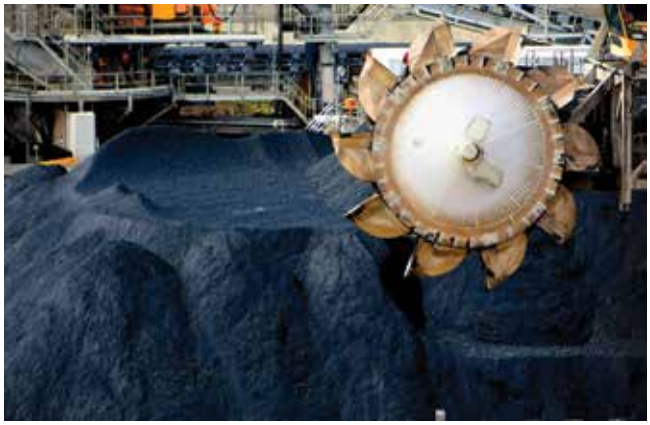
Exports blocked

Australian coal exports to China have been formally blocked after months of import restrictions that have thrown the $14 billion export industry into turmoil.

The decision means Australian coal will be blocked indefinitely while China bolsters imports from Mongolia, Indonesia, and Russia, and expands local production.

China's international state media outlet, *The Global Times* reported China's National Development and Reform Commission had given approval to power plants to import coal "without clearance restrictions, except for Australia, in a bid to stabilise coal purchase prices".

Australia's Trade Minister Simon Birmingham has urged Chinese authorities to "immediately rule out the reports". According to him, if accurate, they would appear to be discriminatory practices against Australian coal.



China 'built over three times as much coal plant capacity as the rest of the world in 2020'

China built more than three times as much new coal power capacity as all the other countries in the world combined last year.

That is according to a new survey by the San Francisco-based think tank Global Energy Monitor (GEM) and the independent organisation Centre for Research on Energy and Clean Air (CREA), which suggests China commissioned 38.4GW of new coal plants last year.

That translates to more than one large coal plant every week.

The research, which surveyed global coal-fired units through to 31st December, also shows 73GW of new coal power projects started in China, which is five times as much as in all other countries.

The report demonstrates China's coal fleet grew by 29.8GW in 2020, while in the rest of the world's net capacity decreased by 17.2GW.

In addition, China was home to 85% of the 87.4GW of proposed new global coal-fired capacity in 2020.

The Chinese President Xi Jinping has recently announced pledge for the country to be carbon-neutral by 2060.

Volt looks at European graphite

Junior Volt Resources has signed a term sheet to potentially acquire a 70% interest in the Zavalievsky graphite business, in the Ukraine.

Zavalievsky is a long-life graphite operation that has been operational for 87 years, and currently produces around 250 000 t/y of crushed granite for road construction and concrete manufacturing. Volt believes that there is potential to substantially increase annual production of crushed granite through the expansion of the crushing and screening equipment.

The Zavalievsky Graphite (ZG) Group has current plans to install a processing plant and equipment to start the production of spheronised purified graphite for the European lithium-ion battery anode market within the next 12 months.

Furthermore, a garnet tailings recovery circuit has also been constructed, but is yet to be commissioned into the operation. The construction of this recovery circuit provides an opportunity to develop a viable industrial garnet business, said Volt, particularly considering the Zavalievsky mine is close proximity to European markets.

Under the terms of the agreement, Volt would potentially acquire a 70% interest in each of the companies comprising the ZG Group, including Zavalievsky Graphite, which owns processing plant and mining equipment, Stone Found LLC, which will entail the crushed granite operations, and Graphite Invest LLC, which holds a 70% interest the mine, land and administration buildings and holds a 79% interest in 636 ha of freehold land in which the Zavalievsky mine, processing plant and other related facilities are located.

Volt would pay a purchase price of $7.5 million for this interest, payable in two instalments of $3.75 million each, with the first instalment due on the completion of the transaction, and the second due six months after the date of that completion.

"We are excited about the potential benefits in acquiring a controlling interest in the ZG Group on Volt's graphite strategy. This is a rare opportunity to acquire an existing graphite business located in Europe at a fraction of the development cost of a new project," said Volt chairperson **Asimwe Kabunga**.

"It has the potential to make Volt a key participant in the supply of graphite into the growing European market with excellent access to other markets in the US and the Middle East."

He said that the company's ability to complete funding for its Bunyu project would also be enhanced by this potential acquisition, to accelerate the transition to a graphite producer with a customer base, sales revenue and cashflow generation along with in-house operating and technical expertise to de-risk the Bunyu development.

Volt has been granted exclusivity until April 23 to complete its due diligence and to finalise the terms of a definitive agreement.

Norton Rose Fulbright advises Appian Capital Advisory on the development of the Serrote Copper/Gold project in Brazil

Global law firm Norton Rose Fulbright has advised Appian Capital Advisory ("Appian") as sponsor on the project financing of the Serrote copper and gold mine in Brazil, owned by Mineração Vale Verde do Brasil Ltda (the "Project"). Appian is the investment advisor to private equity funds of over US$1.2bn that invest solely in mining and mining-related companies.

The financing package includes a US$140m committed senior secured project financing facility from ING Capital LLC, Société Genéralé and Natixis, New York Branch, as well as an uncommitted accordion facility for up to US$20m and working capital trade financing from a major international trader. The intention is that a royalty is also purchased in the Project. The financing package will be used for completion of the construction of the 4.1 million tonnes per annum Project, expected to achieve first production in the second half of 2021.

Martin McCann, partner and Global Head of Business at Norton Rose Fulbright, comments:

"We are delighted to have assisted Appian, a long-term PE client, and the other parties to achieve close. It is not easy to close a project financing in a global pandemic and it is a testament to the hard work of all parties to get this over the line. Our deal pipeline is incredibly strong for 2021, including other major Brazilian developments. People imagine that it's only our gold business has been busy this year. However, all of the battery metals and copper remain very strong driven from Lat Am and Africa. This is part of the energy transition we see dominating mining for the next decade. We see many new deals being driven by private equity and debt funds going forwards."

The multi-jurisdictional Norton Rose Fulbright team was led by Martin McCann and senior associate Felicity Brown, with assistance from partners Jon Perry, Daniel Franks, counsel Richard Blackburn and associate Temi Adetugbo in the London office. Partner Noam Ayali and senior associate Rachel Crouch in the Washington office advised on New York law matters. Partner Charles Johnson and senior associate Diego Brandao provided assistance on Brazilian matters, and partners Bart Le Blanc, Joris Ravelli, senior associate Yannick Schuerman and associate Sam Jonkeren advised on Dutch law matters.

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RMX's rare earth results could spark catalysts to come

Promising results from an assessment of radiometric data at Red Mountain Mining's Mt Mansbridge heavy rare earths (HREE) project has put the company in a strong position to reach several milestones in the coming months.

Red Mountain acquired the Mt Mansbridge HREE project in December 2020.

Mt Mansbridge is a Kimberley's based heavy rare earths and nickel-cobalt project, and at the time of acquisition management noted that heavy rare earths were a critical and strategic component of the modern economy and that this was being reflected in recent healthy price rises in November, particularly in relation to dysprosium and terbium.

Rare earths have become the key ingredient of many of the devices and technologies used daily including magnets and super magnets, motors, metal alloys, electronic and computing equipment, batteries, catalytic converters, petroleum refining, medical imaging, colouring agents in glass and ceramics, phosphors, lasers, and special glass.

They can make electronic parts smaller and faster, magnets more powerful, metal alloys stronger, flat screen TV pictures brighter, chemical reactions faster, fuel cells more efficient (for some types of hybrid cars) and pollution control better.

China controls over 70% of the supply of rare earths and account for up to 98% of global heavy rare earth production, however recently announced that it would severely restrict its exports of rare earth elements due to rising environmental problems with its mines, polluted waterways and radiation exposure affecting not only workers but entire communities.

From this, global interest for new, sustainable sources of heavy rare earth supply outside of China has grown substantially.

Mt Mansbridge could, thus, be a strategic asset, prospective for critical and high value heavy rare earths, providing investors exposure to heavy rare earths.

The latest results stem from recent airborne radiometric survey data, which identified 32 priority heavy rare earth element/ dysprosium targets along 33 kilometres of prospective unconformity. The targets are analogous to Northern Minerals' unconformity related HREE deposits Dazzler and Iceman.

It is worth noting that shares in Northern Minerals have responded positively to the buoyant commodity environment since November, doubling to a 12 month high of 6.7 cents in late January.

Catalysts could revisit 12 month high

This latest news may be the catalyst required to revisit the 12 month share price high that was made only a month ago.

In discussing the survey results released recently, RMX highlighted Mt Mansbridge South is a prospect with known xenotime mineralisation.

This is considered particularly encouraging as it validates the exploration technique as an effective method of identifying areas prospective for HREE mineralisation.

The company has already begun planning access with relevant native title claimant groups, with an anticipated initial reconnaissance trip to review prioritised targets in the June quarter of 2021 once the project is accessible with drilling anticipated to commence in June 2021.

Improved surveying technologies pay dividends for Red Mountain

In HREE/Xenotime deposits, radiometric data has proven to be valuable in vectoring in on HREE targets.

At Mt Mansbridge, the collection of more informative data when compared with historical surveys has paid off for Red Mountain.

Processing and ratioing of the newly acquired 800-kilometre line airborne radiometric data set has identified and delineated 32 additional basement and unconformity related HREE/ Xenotime targets for further exploration.

These newly identified targets are in addition to the previously reported areas of known Xenotime mineralisation at Mt Mansbridge' and Mt Mansbridge South, the Killi Killi HREE geochemical anomaly and previously reported radiometric anomalies.

All these targets are summarised below and will be the focus of exploration in the June quarter.

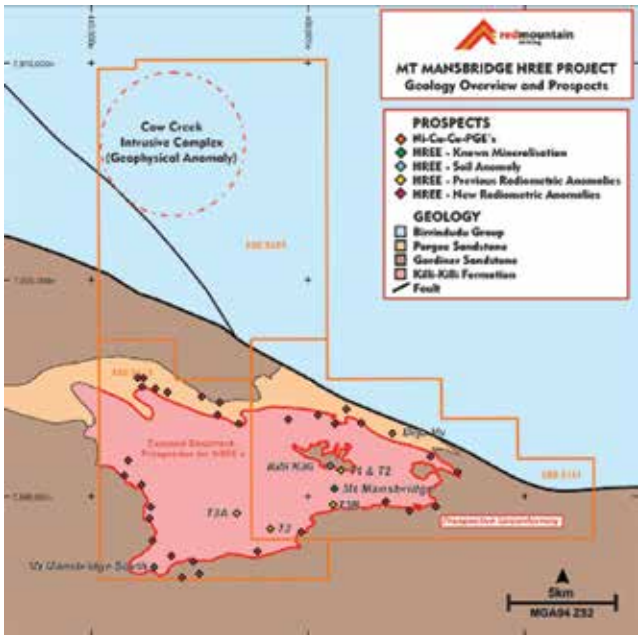
The Mt Mansbridge South prospect is one of the two prospects within the project area with observed xenotime mineralisation.

Processing of the radiometric data highlighted the area as prospective for HREE/Xenotime.

The company views this as a validation of the radiometric data set as a targeting method for HREE/Xenotime mineralisation.

Due to the positive radiometric response over the Mt Mansbridge South prospect, similar radiometric anomalies in the vicinity have been identified and prioritised as exploration targets.

RMX is fast tracking exploration and development at Mt Mansbridge to try to capitalise on the current demand for heavy HREE and the strengthening demand for nickel-cobalt.



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