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Septentrio GPS/ GNSS for mining in the toughest environments

Deep in the amazon jungle, in November 2021, mining works are underway. Jim Elkins flew from Arizona to visit the mine, answering an urgent call for help: GPS receivers aboard the drill rigs were not working. Jim is a specialist in mining and automation, working for Flanders, a US-based company with expertise in electrical machinery and control systems. Flanders pioneers machine control technology that takes mining efficiency to the next level. The drills rigs at the mine create holes with centimeter precision, ensuring optimal fragmentation of rock. This makes subsequent jobs like stone extraction and removal faster and easier.

ROBUST GNSS WORKS IN ANY ENVIRONMENT

Difficult environments such as areas close to the equator, or to the poles can pose a challenge for GPS receivers. These places tend to experience the most intense ionospheric scintillations, which are fluctuations in electron density in the ionosphere. Such scintillations effect GPS/GNSS signals that travel from space to Earth causing degradation of accuracy or even positioning loss. To fix the GPS problem in the amazon mine, and to resume the mining process, Jim helped install the ARDVARC control system, replacing all the GPS receivers aboard the drill rigs with Septentrio AsteRx-U GNSS* receivers. These receivers are robust inside and out. Housed in a tough IP67 enclosure they run Septentrio's proprietary GNSS+ algorithms including IONO+, which ensures high accuracy positioning even during ionospheric scintillations. With AsteRx-U receivers onboard the drill rigs resumed their work immediately, preparing the ground for the next blast.

"We've had Septentrio GNSS receivers in our control systems for the last 3 years and I've never had any complaints about accuracy or integration. The AsteRx-U is extremely accurate and operates in difficult environments in places like Brazil, western Australia, South Africa as well as North America."

Jim Elkins, Global Business Development, Mining and Automation, Flanders

THE ARDVAC DRILL CONTROL SYSTEM WITH THE TOUGHEST GNSS

- Operates fully autonomously with auto-propel and autonomous movement from hole to hole
- Multiple machines are monitored by a single person from a safe distance
- AsteRx-U multi-frequency multi-constellation GPS/ GNSS receivers for positioning accuracy within 10 cm
  - IONO+ ionospheric scintillation protection in places of high solar activity
  - LOCK+ robust signal tracking during strong vibrations or shocks
  - AIM+ Advanced Interference Mitigation technology protects against RF interference known as jamming

**Global Navigation Satellite System including the American GPS, European Galileo, Russian GLONASS, Chinese BeiDou, Japan's QZSS and India's NavIC. These satellite constellations broadcast positioning information to receivers which use it to calculate their absolute position.*

The ARDVARC control systems use AsteRx-U receivers, which run advanced GNSS+ algorithms including IONO+ for robust operation in areas of intense solar activity

US coal use is rebounding under Biden like it never did with Trump

Donald Trump vowed to revive the coal industry, but it is President Joe Biden who is seeing a big comeback of the dirtiest fossil fuel.

US power plants are on track to burn 23% more coal this year, the first increase since 2013, despite Biden's ambitious plan to eliminate carbon emissions from the power grid. The rebound comes after consumption by utilities plunged 36% under Trump, who slashed environmental regulations in an unsuccessful effort to boost the fuel.

That is going to increase emissions at a time when Biden and other world leaders prepare to gather in Scotland in a few weeks, hoping to reach a deal on curbing fossil fuels in a final effort to save the world from climate change. The boom is being driven by surging natural gas prices and a global energy crisis that is forcing countries to burn dirtier fuels to keep up with demand. It is also a stark reminder that government policy can steer energy markets, but it cannot control them.

"Over the short term, the market will always dominate," said Jeremy Fisher, senior adviser for the Sierra Club's environmental law program.

As the world emerges from the coronavirus pandemic, reopening economies are driving a huge rebound for power demand. But natural gas is in short supply, creating shortfalls at a time when wind and hydro have been unreliable in some regions. Europe and Asia have been hit the worst, with skyrocketing markets, blackouts in places like India, power shortages in China and the threat of outages in other countries. Energy prices are also soaring in the US, though not to the same extremes.

The situation is driving up coal demand around the world, and in the US, utilities are cranking up aging power plants and miners are digging up as much as they can.

The shift means that coal will supply about 24% of US electricity this year, after falling to 20% in 2021, an historic low after years of efforts to push utilities toward clean power and amid cheap natural gas supplies. That resurgence may look even more extreme when the Energy Department releases its latest monthly report.

`Markets have spoken'

"The markets have spoken," said Rich Nolan, CEO of the National Mining Association. "We're seeing the essential nature of coal come roaring back. "In 2021, the US utilities are poised to burn 536.9-million short tons of coal, up from 436.5 million in 2020, the Energy Information Administration forecasts.

Coal from the central Appalachia region has climbed 39% since the start of the year to $75.50 a ton, the highest since May 2019. Prices in other regions are lower, but also on the rise.

Demand for coal will remain strong into next year, said Ernie Thrasher, CEO of Xcoal Energy & Resources, the biggest US exporter of the fuel. Supply is already constrained, and Thrasher said he is hearing some utilities express concern that they may face fuel shortages over the next several months as colder weather pushes energy demand higher to heat homes.

"It won't be easy this winter," he said.

Kevin Book, managing director of research firm Clearview Energy Partners, said the current crisis has added fodder to the debate over efforts to move away from coal.

"The goal of policy, if you listen to what's being said in Western countries in the context of climate discussions, is not only to stop building new coal but to eliminate the existing capacity to burn coal," Book said. "This is a moment in time when that idea is going to be challenged."

Short-lived boom?

While the coal boom is dramatic, the moment may be short-lived.

Global pressure to curb carbon emissions remains strong, and in the long-term, "policy absolutely matters," said Cara Bottorff, a senior energy sector analyst at the Sierra Club.

Global energy crisis shows fragility of clean-power era

Coal consumption plunged under Trump largely because utilities shifted to gas, which was far cheaper at the time, and increasingly embraced renewables as the cost of wind and solar fell. The decline was also the result of key policy decisions from his predecessor Barack Obama. And though Trump sought to revive the industry, legal challenges and the risk of an unpredictable regulatory environment discouraged long-term investments in coal.

Coal mining and generating capacity declined 40% over the past six years, according to B. Riley Securities.

Similarly, Biden's policies will eventually lead to further reductions in coal use. He is pursuing structural changes including tax incentives and new market rules that will drive decisions at energy companies.

"The transition is well under way, but it won't be over tomorrow," said Dennis Wamsted, an analyst for the Institute for Energy Economics and Financial Analysis.

Ministry launches auction process of 40 new mines

After successful auction of 28 coal mines in the first two tranches, Ministry of Coal has launched the auction process of forty new coal mines (21new mines under CM(SP) Act and nineteen new mines under the Tranche 3 of MMDR Act). With coal mines rolling over from previous tranche, there shall be a total of 88 coal mines on offer.

Total geological resources of about 55 billion tonnes of coal are on offer from these 88 mines, of which 57 are fully explored mines and 31 are partially explored mines. There are four coking coal mines on offer. Mines are spread across ten coal bearing states of Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, Maharashtra, West Bengal, Andhra Pradesh, Telangana, Arunachal Pradesh, and Assam.

From this tranche onwards, Ministry of Coal has introduced provisions in the Agreement related to

i Sustainable mining operations, including mine closure.
ii Mechanised evacuation of coal; and (iii) Surrender of coal mine by Successful Bidder upon encountering difficult mining conditions.

The list of mines has been finalised post detailed deliberations and mines falling under protected areas, wildlife sanctuaries, critical habitats, having forest cover greater than 40%, heavily built-up area etc. have been excluded.

Key features of auction process include introduction of National Coal Index, ease in participation with no restriction for prior coal mining experience, full flexibility in coal utilisation, optimised payment structures, efficiency promotion through incentives for early production and use of clean coal technology. Further incentives are being contemplated by the Ministry of Coal with focus on sustainability.

Addressing the function, Union Minister of Coal, Mines & Parliamentary Affairs, Pralhad Joshi stressed that the Ministry of Coal and the Government of India, under the leadership of Prime Minister Narendra Modi, are on a continuous journey to reform the coal sector and unlock values for the nation's economy.

Minister Joshi threw light on the energy consumption pattern of the country and how the demand of power has increased by around 20% compared to pre-Covid times. The Minister emphasised that India is currently one of the lowest in terms of per capita consumption of power as compared to the developed countries and that the power demand of the country is expected to be doubled by the year 2040 owing to the major steps taken by the Government in connecting the remotest of the places with power and reiterated that the coal will continue to play a major part in the energy mix of the country for next 35-40 years.

Union Minister of Coal also announced that the earlier rebate of 20% on the final offer on sale or consumption of coal for coal gasification / liquefaction, may be increased. The Minister also informed that discussions are in progress for incentives for the coking coal blocks. These steps will help in increasing the participation of prospective bidders.

On the occasion, Minister of State for Coal, Mines & Railways, Raosaheb Patel Danve, stressed that the coal sector is going to play a significant role in realising the vision of a 5 trillion-dollar Indian economy. The Minister emphasized that a lot of steps have been taken by the Ministry of Coal for enhancing the production of coal like introduction of commercial mining, reduction in payments by the bidders, removal of the eligibility criteria for participation in the coal block auctions thereby ensuring maximum participation from the bidders which will lead to the enhanced production of coal. He laid stress on the recent policy amendments allowing the captive miners to sell up to 50% of the annual production of coal.

Addressing the gathering, Secretary, Ministry of Coal, informed that the prices of imported coal has increased two to three time and it paved the way for utilising more of the domestic coal thereby reducing the imports. This has been possible due to the various initiatives taken by the Ministry of Coal like allowing commercial mining, allowing enhanced production over and above the production as per the mining plan, providing incentives to the bidders, reduction in payments, allowing captive miners to sell coal etc. These steps have ensured that dependence on coal imports is reduced and that the domestic production is increased to meet the coal demand of the country.

Earlier, welcoming the guests and potential bidders, the Additional Secretary and Nominated Authority, Ministry of Coal, M Nagaraju emphasised the need of augmenting domestic coal production, considering the rise in international coal and oil prices, and that potential investors may secure a coal mine for themselves.

The commencement of sale of tender document started from 12th October 2021. Details of the mines, auction terms, timelines etc. can be accessed on MSTC auction platform. The auction shall be held online through a transparent two stage process, based on Percentage Revenue Share. This round of auction will be the 13th Tranche of auction under CMSP Act and 3rd Tranche of auction under MMDR Act.

SBI Capital Markets Limited, sole Transaction Advisor to Ministry of Coal for the commercial coal mine auction, had devised the methodology and is assisting the Ministry of Coal in conduct of the auction.

A total of 88 coal mines with cumulative PRC of 282 MT are on offer of which 35 coal mines are under 13th Tranche of auction under CMSP Act and 53 coal mines are under 3rd Tranche of auction under MMDR Act. Out of these 88 coal mines, forty are new coal mines whereas the remaining 48 coal mines are roll over mines from the earlier round of auctions. The mines on offer are having 57 fully explored while 31 partially explored coal mines. The list also includes four coking coal mines.

Third new coal project approved by Australian environment minister Sussan Ley

Australian Environment Minister Sussan Ley has approved a third coal mine extension in the space of a month. The extension at Glencore's Mangoola thermal coal mine in New South Wales follows extensions at the Whitehaven coal mine and the Wollongong coal mine in September.

The extension at the Glencore site will allow the mine to run for another eight years and produce 52 million tonnes of coal. In a statement covering the reasons for the approval of extension, Australian Environment Minister Sussan Ley stated: "The mine itself will contribute approximately 0.00073 % to global emissions per annum."

She continued: "Based on this estimate, (the mine) … is unlikely to influence global emissions and climate change trajectories."

Glencore had stated that the mine would create upwards of 100 construction jobs and secure ongoing employment for Mangoola's workforce of approximately 400 employees. In addition, the miner noted that it had invested more than five years in detailed studies and consultation from the project.

Climate controversy

However, the decision has caused significant controversy, especially in the lead up to COP26, where the phasing out of coal power will be one of the main talking points.

Australia is the world's biggest coal exporter. In 2020, the export value of coal from Australia was approximately A$54.62bn. The country has also yet to sign up for commitments for net-zero carbon emissions by 2050, leading critics and climate campaigners to lambast the government for inaction on climate change.

The extension also follows a federal court decision in July declared that the nation's environment minister has a "duty to take reasonable care" that young people won't be harmed or killed by carbon dioxide emissions if she approves a coal mine expansion.

Our industry is getting ample funding to pile into new plants

Russia's government is betting that coal consumption will continue to rise in big Asian markets like China even as it dries up elsewhere.

The coal industry is still getting enough funding to enable significant investments in the world's dirtiest fossil fuel, according to a report from German campaign group Urgewald.

Half the 1,030 companies surveyed in the study are planning to develop new coal power plants, new coal mines or new coal transport infrastructure. Less than 5% of the firms on the Global Coal Exit List have announced a coal exit date, according to the report.

"As long as investors, banks, and insurers … continue supporting the companies listed on the GCEL, it will be impossible to phase out coal in time," said Heffa Schuecking, the director of Urgewald. "Ending support for all coal developers must become an immediate priority for financial institutions worldwide."

The study shows that much of the rhetoric dedicated to addressing climate change is not reflected in the numbers. Meanwhile, coal prices have surged amid a global energy crisis that threatens to undermine commitment to cutting CO2 emissions. China this month ordered its banks to ramp up funding to coal and energy companies to ease a power crunch ahead of the winter.

The GCEL list covers the largest coal plant operators, defined as companies that

get over 20% of their power or revenues from coal and companies that are planning to expand coal mining, coal power or coal infrastructure.

The Urgewald study comes less than a month before world leaders are due to gather in Glasgow, Scotland, to hold the 26th UN Climate Change Conference of the Parties. Talks are set to be shaped by the latest assessment by the United Nations Intergovernmental Panel on Climate Change, which found that the planet is overheating at a more alarming pace than previously feared and that cutting greenhouse gas emissions is the only way to avert a climate catastrophe.

South Africa should not rush its transition away minister says

South Africa must manage its transition away from coal-fired power generation systematically and not rush a switch to renewable energy sources, Mining and Energy Minister Gwede Mantashe said.

"I am not saying coal for ever, … I am saying let us manage our transition step by step rather than being emotional," Mantashe told a mining conference, when asked how China's pledge to not build new coal power stations abroad would affect South Africa. "We are not a developed economy, we don't have all alternative sources," he added.

Inner Mongolia Mines Ordered to Boost Production by 55%

Seventy-two coal mines in North China's Inner Mongolia autonomous region have been told to boost their output by nearly 100 million tons, as the nation continues to grapple with severe power shortages.

An urgent notice issued by Inner Mongolia's energy bureau gave the nod to seventy-two mines in the three cities of Wuhai, Ordos, Hulunbuir and the region of Xilingol league to raise annual production capacity by 98.35 million tons, or 55.11%, provided they do so safely.

Under the directive, which comes as part of a broader drive to grow China's core coal capacity, mines were told to complete procedures for the increase by the end of the month. But it is unclear how long that will take to translate into actual output.

IEA warns of more energy market volatility as transition investment lags

There is a looming risk of more turbulence ahead for energy markets, the International Energy Agency (IEA) warns in its latest World Energy Outlook publication.

"The world is not investing enough to meet its future energy needs, and uncertainties over policies and demand trajectories create a strong risk of a volatile period ahead for energy markets," the 2021 edition of the flagship report warns.

Released against the backdrop of fuel shortages and surging energy prices across the world, but particularly in the UK and parts of Europe and Asia, the report states that transition-related spending is currently inadequate to meet rising demand for energy services in a sustainable way.

Investments are also falling well short of what is required for limiting global warming to 1.5 °C above pre-industrial levels, as contained in the report's net zero emissions (NZE) scenario.

Global average temperatures are already 1.1 °C higher than those of the pre-industrial age, with visible impacts on weather and climate extremes.

$4-trillion-a-year by 2030

To achieve the NZE pathway, yearly investments in clean energy would have to rise to $4 trillion by 2030, more than triple today's levels.

Much of this investment, the report says, would have to be directed towards four key measures to "keep a 1.5 °C path within reach", including: a massive additional push for clean electrification; a relentless focus on energy efficiency, a broad drive to cut methane emissions from fossil fuel operations; and a big boost to clean energy innovation.

"There is a looming risk of more turbulence for global energy markets," executive director Dr Fatih Birol warns, with the report pointing to deficits across all sectors and regions.

While investments in wind, solar and electric vehicles are gaining momentum, the pace remains too slow to reach net zero emissions by mid-century and to compensate for lower fossil fuel spending that is currently geared towards a world of stagnant or even falling demand.

The amount being spent on oil and natural gas has also been dragged down by two price collapses in 2014/15 and in 2020.

Boosting deployments of clean energy technologies and infrastructure provides a way out of the impasse, but the IEA stresses that it needs to happen quickly, or global energy markets will face a turbulent and volatile period ahead.

"Clear signals and direction from policy makers are essential. If the road ahead is paved only with good intentions, then it will be a bumpy ride indeed."

Stubborn incumbency

Birol warns, too, that the world's encouraging clean energy momentum is running up against the "stubborn incumbency" of fossil fuels in energy systems.

The world's consumption of coal, for instance, is set to strongly grow this year, pushing carbon dioxide emissions towards their second largest annual increase in history.

However, under all scenarios presented in the report, coal use is estimated to decline – a fall that could be accelerated further by China's recent announcement of an end to its support for building coal plants abroad.

"Governments need to resolve this at COP26 by giving a clear and unmistakeable signal that they are committed to rapidly scaling up the clean and resilient technologies of the future.

"The social and economic benefits of accelerating clean energy transitions are huge, and the costs of inaction are immense," Birol adds.

Beside the NZE scenario, the report also includes a newly modelled Announced Pledges Scenario, or APS, based on country decarbonisation commitments made ahead of the upcoming COP26 climate talks, as well as the usual Stated Policies Scenario (STEPS), which reflects specific policy initiatives either in place or under development.

For the first time, oil demand is shown to go into eventual decline in all the scenarios, although the timing and speed of the drop vary widely.

In fact, the IEA describes the differences in the outcomes of the APS and NZE as "stark," with current climate pledges resulting in only 20% of the emissions reduction by 2030 that is necessary to put the world on a path towards net zero by 2050.

Under the STEPS, meanwhile, yearly emissions would remain around current levels by 2050, which would result in global average temperatures still rising when they hit 2.6 °C above pre-industrial levels in 2100.

"If all today's announced climate pledges are met, the world would still be consuming 75-million oil barrels per day by 2050 – down from around 100-million today – but that plummets to 25-million in the NZE by 2050 scenario."

Natural gas demand increases in all scenarios over the next five years, but there are sharp divergences thereafter.

Finance is the "missing link" to accelerate clean energy deployment in developing economies, with some 70% of the additional spending required to close the gap between the APS and NZE needed in emerging market and developing economies.

The report also states that fulfilling the commitment by advanced economies to mobilise $100 billion a year in climate finance to support developing countries "is necessary, but not sufficient".

"An international catalyst is essential to accelerate flows of capital in support of energy transitions and allow developing economies to chart a new lower-emissions path for development," the IEA states.

It adds that most transition-related energy investment will need to be carried out by private developers, consumers and financiers responding to market signals and policies set by governments.

"Alongside the necessary policy and regulatory reforms, public financial institutions – led by international development banks and larger climate finance commitments from advanced economies – play crucial roles to bring forward investment in areas where private players do not yet see the right balance of risk and reward."

BHP sells QLD coal mines to Stanmore for $1.8bn

BHP has agreed to sell its 80% share in BHP Mitsui Coal (BMC) to Stanmore Resources, offloading two Queensland coal mines and associated infrastructure.

BMC owns the Poitrel and South Walker Creek metallurgical coal mines, plus Red Mountain Infrastructure, and the Wards Well development.

The sale will see up to $US1.35bn ($1.82bn) change hands, with $1.1bn to occur upon completion of the share sale and purchase agreement.

BHP Minerals Australia president Edgar Basto said the deal continued the company's transition from large carbon emitting operations.

"This transaction is consistent with BHP's strategy, delivers value for our company and shareholders and provides certainty for BMC's workforce and the local community," Basto said.

"South Walker Creek and Poitrel are well-run assets that have been an important part of our portfolio for many years, and we are grateful for their contribution to BHP."

Poitrel and South Walker Creek have a combined metallurgical coal production of about 10m marketable reserves of more than 135m tonnes, according to Stanmore.

Golden Energy and Resources (GEAR) – Stanmore's parent company – were very supportive of the deal, according to Stanmore chief executive officer Marcelo Matos.

"This is an exciting and transformative acquisition for Stanmore, and we are fortunate to be able to rely on the full support received from our controlling shareholders, GEAR as well as the Sinar Mas Group, to successfully execute this deal," Matos said.

"This transaction will see the company become one of the leading metallurgical coal producers globally and provide Stanmore with a portfolio of Tier 1 assets. "(It brings) significantly increased reserves and resources base and assets with an expected mine life exceeding 25 years production, positioning the company for substantial cashflow generation and future growth opportunities."

The deal will increase Stanmore's metallurgical coal production by a multiple of 5.6, while its coal reserves will increase by a multiple of 4.2.

India says crisis could drag on as long as six months

India could face upto six months battling to ensure coal-fired power plants have enough fuel as the nation's energy crisis escalates.

More than half the nation's plants are on alert for outages after surging electricity demand and a slump in local coal output eroded stockpiles. Power stations had an average of four days' worth of coal recently, the lowest level in years, and down from 13 days at the start of August.

"I don't know whether I will be comfortable in the next five to six, four to five months," Power Minister Raj Kumar Singh was quoted as telling The Indian Express in an interview published Tuesday. While demand does typically slow with cooler weather from mid-October, "it's going to be touch and go," he said.

In at least a portion of India's coal fleet the situation has deteriorated in the past week, according to Singh. Coal plants accounting for between forty gigawatts to fifty gigawatts of capacity currently have less than three days' of fuel stocks, he told the newspaper. That compares to a total national coal capacity of about 203 gigawatts.

Read more: Energy Crisis Deepens in India as Power Plants Face Outages

Coal accounts for about 70% of India's electricity generation, and consumption is forecast to rise in the next few years, even as Prime Minister Narendra Modi pushes for a massive increase in renewables. Like neighbouring China, India is suffering from the impacts of a sharp surge in electricity demand, a squeeze on domestic mine output and surging prices of seaborne coal.

Government ministries are working with state-run Coal India Ltd. and NTPC Ltd., India's largest power generator, to raise output from mines and to ensure demand is met, Singh was quoted as saying.

Coal supply will be prioritized to utilities that have made regular payments to coal companies, and that have been maintaining mandated levels of fuel stocks, according to the newspaper.

Global energy crisis drives US prices to two-year high

The global energy crisis is rippling into US coal markets, with prices hitting a two year high due to surging demand and years of supply cuts.

Coal from the central Appalachia region rose $2.20 to $73.25 a ton for the week ending October 1, according to government data released Monday. That is up 35% from the start of the year and the highest since May 2019. Prices in other regions are lower but are following the same upward path.

High natural gas prices are prompting US utilities to switch to coal this year, but their ability to fire up coal power plants is constrained by miners that have cut capacity by 40% over the past six years, according to Lucas Pipes, an analyst with B Riley Securities. As the world steps up efforts to curb climate change, the long-term outlook for coal is grim and US producers of the dirtiest fossil fuel have been closing mines and reducing output. With winter on the horizon, gas prices are expected to remain high, and that will continue to keep upward pressure on coal as well.

"Investors are underappreciating the structural changes that have taken place in the North American energy landscape that could lead to these higher prices persisting for some time," Pipes wrote in a research note Monday. "Chief among them, in our opinion, is a dramatically smaller coal generating and mine supply footprint, which limits gas-to-coal switching"

The global energy crisis has sparked demand for coal around the world, with consumption from U.S. electricity producers expected to climb 23% this year, according to the Energy Information Administration. As utilities burn through their stockpiles, inventories at power plants are on track to fall by more than half.

US coal production has been falling steadily since 2008, with total production this year expected to reach about 601 million tons. While that is up significantly from 2020 when the pandemic dragged down demand for electricity, it is still well below 2019 levels. But even if demand remains strong next year, miners may struggle to increase supply.

"Coal supply bottlenecks are already emerging," Pipes said. "It is difficult for the industry to increase output by more than 10% from 2021 levels, limiting gas to coal switching."

Beyond Thar

China has announced, at international forums, that it will not finance any new coal-fired power plant project outside its country anymore. This has sent shock waves among stakeholders in Pakistan who were counting on technology and finance from China to use the huge Thar coal deposits of 185 billion tonnes in the country.

China has already built a 660 MW power plant in Thar and is in the process of building another plant along with a coal mine with a capacity of 1320 MW. There are several other Thar-based coal projects in the pipeline, all reliant on technology and finance from China. It has also built three power plants in Pakistan based on imported coal. There were other project ideas and proposals regarding coal gasification to produce diesel, gas, fertilisers, and chemicals on which considerations were at various stages.

Also, there were project proposals to transport Thar Lignite coal to outside of Thar and use it in place of imported coal – creating a 20-80% mix of Thar Lignite and imported coal. A railway extension project has been developed for the same.

Hopefully, China will honour its existing commitments regarding Thar coal, which are not beyond the current two projects: one has already been constructed (SECMC 660 MW) and the other is under construction (SSRL 1320 MW).

In Pakistan, coal is not used in the power sector alone. The cement sector, too, uses imported coal along with some sub-bituminous coal produced in underground coal mines in Balochistan. Before the advent of coal-based power plants, Pakistan imported 10.7 million tonnes of coal, in 2017 – almost all of it went to the cement sector. Its installed capacity is projected to grow to one hundred million tonnes per annum (mtpa) from the existing 55mtpa. Thus, the cement sector's coal demand is going to be 20mtpa in the near to mid-term future. The sector is vital for both the domestic construction industry and exports. The total imported coal demand for both the power and cement sectors appears to be touching 25mtpa, which will go up to 35mtpa. Based on an average price of $100 per tonne, the total annual import bill for 25mtpa is $2.5 billion.

There is no economic fuel for producing cement other than coal. Previously, cheap local gas was used for producing cement. Rising gas prices and depleting local gas resources have forced cement producers to shift to coal. Unfortunately, now both gas (LNG) and coal are expensive. Coal prices have gone as high as $146 per tonne from the previous $70 per tonne. LNG prices are exceeding $36 per mmbtu, which is uneconomic and unaffordable.

In this context, local coal production is cheaper and viable. Although there has been controversy over Thar coal production costs, recent estimates suggest that the production capacity of $30 per tonne of Thar coal is equivalent to that of $60 per tonne of imported coal. Thar Lignite coal is one-half in calorific value than imported coal. Lignite may not be an ideal fuel for cement production as it contains 40-50% moisture. However, it can be pre-processed to fire in cement kilns. The cement industry is quite progressive in Pakistan. It has been trying to use municipal solid waste to reduce production costs and solve the community's waste problem.

A 20mtpa demand of imported coal from cement factories will be tantamount to 40mtpa of Thar Lignite. Add another ten mtpa for other sectors and it will add up to 50mtpa of Thar coal demand for sectors other than the power sector. If this import is replaced, the country could save $2 billion of foreign exchange. It is, therefore, vital for Pakistan to establish Thar Lignite mines with a capacity of 50mtpa in the next five years, even if we forget about the use of Thar coal in the power sector.

It may be plausible that the present undertaking or announcement of China is restricted to only coal-based power plants and that there is no bar on the use of coal in other sectors such as cement. Pakistan should also start developing indigenous mine development and operating capacity. It now has some experience in this respect. The Chinese government may also be more than willing to transfer technology in this sector (by reducing its direct exposure in terms of operations and finance) now that it wants to improve its international image among the world's climate lobbies.

Pakistan started its Thar coal venture quite late, while in India, across the border in the same Thar desert, its utilisation started in the 1970s. Except China, no other country was ready to extend cooperation in this field, and it did. It appears that it cannot do any more than the existing commitments. The need of the hour is to start developing and absorbing local coal mining capabilities projects and develop independence.

It should be noted that coal-based power, whether local or based on imported coal, is expensive at 8.5 USc per kWh while renewable energy like solar is available at less than 4 USc. International prices have gone down to even 2 USc and less. There are predictions that solar power might go as low as one USc, although storage cost would double it.

The issue is how to manage the transition and avoid stranded investments. China's decision may prove to be a blessing in disguise. Thar, which is an area of 10,000 sq kms, can generate 400 GW solar electricity based on twenty-five sq kms per GW. By comparison, the Indicative Generation Capacity Expansion Plan (IGCEP) predicts 55-75 GW of generating capacity by 2030. Although all electricity cannot be produced in one location, it may be reasonable to plan up to 10,000 MW of solar power in Thar. It is quite possible that some large capital-extensive projects may be dropped for a variety of reasons. The IGCEP is indicative.

We should not repeat the same mistake of high foreign reliance. A local solar equipment production industry development plan should be developed, not only for producing solar PV panels but also for other items such as inverters. An incentive programme should be prepared to encourage the local manufacturing industry. After all, huge incentives in the form of custom tariffs have been given to the automotive industry. And now, there are proposals for the 10% price protection for the refinery sector.

There is ample scope for incentives when we compare coal-based electricity tariff of 8.5 USc vs under 4 USc for solar power. India, Turkey, and other countries have similar incentive system, and they have developed their solar industries along with the installation of substantial solar power capacity. Thus, local manufacturing and installation of solar power capacity are not incompatible.

As of today, no energy source is a panacea. Solar is available only during the day while hydro and wind energies are available in summer. Fossil fuels such as oil and gas are exhaustible and subject to price variations, while coal is bad for the environment and climate.

The days of energy utopia are not far – the targets can be achieved by between 2040 and 2050. The world is moving towards the solar-wind-hydrogen chain. Hydrogen will make energy transportable and tradable across national boundaries. We must start moving in that direction too.

The writer is a former member of the Energy Planning Commission and author of 'Pakistan's Energy Issues: Success and Challenges.'

Properties of wire ropes

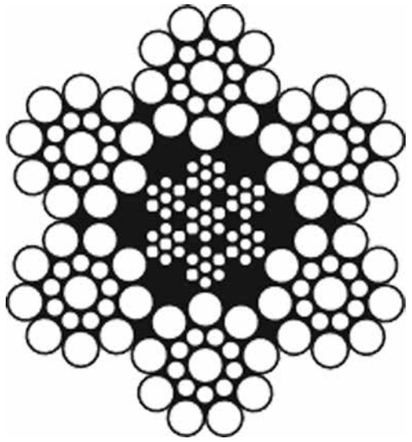
The failure of a steel wire rope while in service is potentially disastrous, particularly when being used as part of a winding system transporting a large number of people in a vertical shaft. Even when not transporting people, a rope failure gives rise to significant risks to people working near the shaft. Any rope failure could cause damage to winding equipment and the shaft itself putting it out of action. Apart from giving rise to very hazardous recovery operations, the loss of one means of egress presents additional risk to everyone below ground. Coal International looks at the properties of wire ropes.

With each application, your choices of wire ropes can be many. How do you know which one works best for you? Ropes include a combination of properties that give them specific performance abilities. Before you choose, it pays to look closely at each rope's special properties.

NO SINGLE WIRE ROPE CAN DO IT ALL

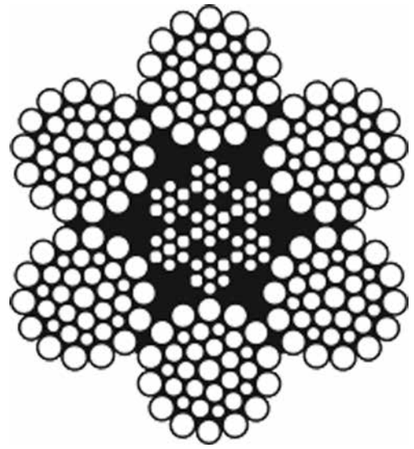
All wire ropes feature design property trade-offs. In most cases, a wire rope cannot increase both fatigue resistance and abrasion resistance. For example, when you increase fatigue resistance by selecting a rope with more wires, the rope will have less abrasion resistance because of its greater number of smaller outer wires.

When you need wire rope with greater abrasion resistance, one choice is a rope with fewer (and larger) outer wires to reduce the effects of surface wear. But that means the rope's fatigue resistance will decrease. That is why you need to choose your wire rope like you would any other machine. Very carefully. You must consider all operating conditions and rope properties.



BENEFIT OF FEWER OUTSIDE WIRES PER STRAND

ABRASION RESISTANCE
> Increases with larger wires
> Decreases with smaller wires.



BENEFIT OF MORE OUTSIDE WIRES PER STRAND

FATIGUE RESISTANCE
> Decreases with larger wires.
> Increases with smaller wires.

THE BASIC PROPERTIES OF WIRE ROPE

How do you choose the wire rope that is best suited for your job? Following are the most common properties to be considered when selecting a rope for an application.

STRENGTH

Wire rope strength in the United States is typically shown in tons of 2,000 lbs. The wire rope strength is shown as minimum breaking force (MBF).

This is a calculated strength that has been accepted by the wire rope industry.

When tested on a tensile machine, a new rope will break at a value equal to – or higher than – the minimum breaking force shown for that rope.

The published values apply to new, unused rope. A rope should never operate at – or near – the minimum breaking force. The minimum breaking force of the rope must be divided by the design factor required for the application to determine the maximum load allowed on the rope. During its useful life, a rope loses strength gradually due to natural causes such as surface wear and metal fatigue.

FATIGUE RESISTANCE

Fatigue resistance involves fatigue of the wires that make up a rope. To have high fatigue resistance, wires must be capable of bending repeatedly under stress – for example, as a loaded rope passes over a sheave during operation.

Increased fatigue resistance is achieved in a rope design by using a large number of wires. It involves both the wire properties and rope construction.

In general, a rope made of many wires will have greater fatigue resistance than a same-size rope made of fewer, larger wires because smaller wires have greater ability to bend as the rope passes over sheaves or around drums. To overcome the effects of fatigue, ropes must never bend over sheaves or drums with a diameter so small as to bend wires excessively. Standards for specific applications contain requirements for minimum sheave and drum sizes.

Every rope is subject to metal fatigue from bending stress while in operation, and therefore the rope's strength gradually diminishes as the rope is used.

CRUSHING RESISTANCE

Crushing is the effect of external pressure on a rope, which damages it by distorting the cross-section shape of the rope, its strands or core – or all three.

Crushing resistance therefore is a rope's ability to withstand or resist external forces, and is a term used to express comparison between ropes.

When a rope is damaged by crushing, the wires, strands and core are prevented from moving and adjusting normally during operation.

In general, IWRC ropes are more crush resistant than fibre core ropes. Regular lay ropes are more crush resistant than lang lay ropes. 6-strand ropes have greater crush resistance than 8-strand ropes or 19-strand ropes. Compacted-strand ropes are more resistant than standard round-strand ropes.

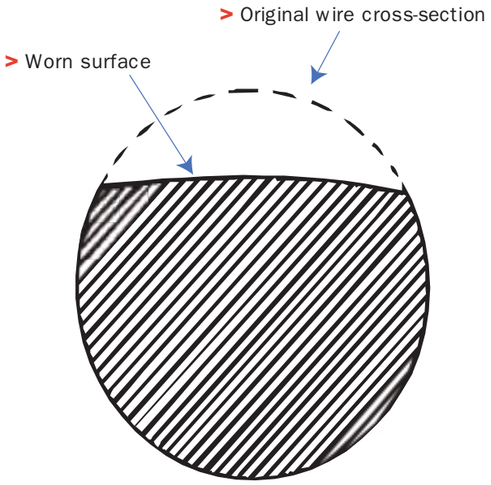
RESISTANCE TO METAL LOSS AND DEFORMATION

Metal loss refers to the actual wearing a way of metal from the outer wires of a rope, and metal deformation is the changing of the shape of outer wires of a rope.

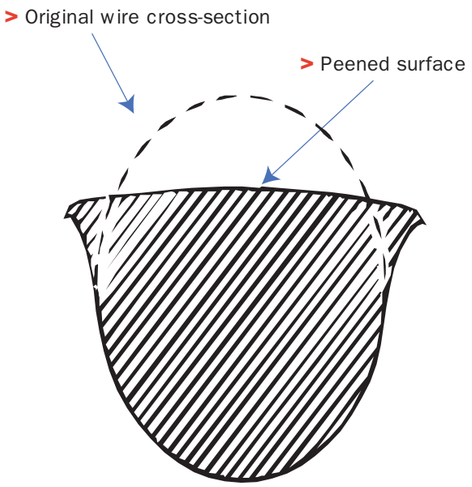
"SQUARED ENDS"
> Typical example of breaks due to fatigue.

"CRUSHING"
> Typical example of external pressure on a wire rope.

CROSS-SECTION OF A WORN WIRE



CROSS-SECTION OF A PEENED WIRE



In general, resistance to metal loss by abrasion (usually called "abrasion resistance") refers to a rope's ability to withstand metal being worn away along its exterior. This reduces strength of a rope.

The most generic form of metal deformation is called "peening" – since outside wires of a peened rope appears to have been "hammered" along their exposed surface.

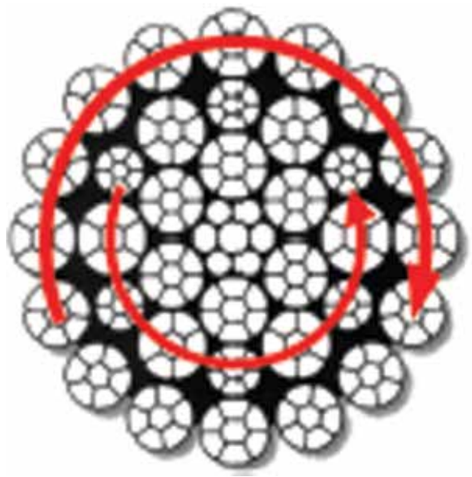
Peening usually occurs on drums, caused by rope-to-rope contact during spooling of the rope on the drum. It may also occur on sheaves.

Peening causes metal fatigue, which in turn may cause wire failure. The hammering – which causes the metal of the wire to flow into a new shape – realigns the grain structure of the metal, thereby affecting its fatigue resistance. The out-of-round shape also impairs wire movement when the rope bends.

RESISTANCE TO ROTATION

When a load is placed on a rope, torque is created within the rope as wires and strands try to straighten out. This is normal and the rope is designed to operate with this load-induced torque. However, this torque can cause both single part and multiple part hoisting systems to rotate. Load-induced torque can be reduced by specially designed ropes.

In standard 6- and 8-strand ropes, the torques produced by the outer strands and the IWRC are in the same direction and add together. In rotation-resistant ropes, the lay of the outer strands is in the opposite direction to the lay of the inner strands, thus the torques produced are in opposite directions and the torques subtract from each other.



Recognising the competitive edge through mining software

Is the mining industry falling behind other global sectors in terms of its adoption of technology? Have companies been reluctant to digitize their operations not only because of the cost of making drastic changes to their processes but also because the complex nature of mining operations makes any overhaul to methods a difficult and time-consuming process?

Many mining processes have remained the same for decades. However, mining companies are beginning to recognize the value and competitive edge that digitization could offer their companies, with software being developed to help plan and optimize operations, automate processes, enhance safety and security, and cut the costs of overheads.

To support this shift, software has evolved to support mining operations in all the different areas where digitization is beneficial. Software is now available for areas such as planning and design to the management of operations covering all areas of mining operations.

EARLY MINING SOFTWARE

The use of computers to aid the mining industry was not established until the 1970s. While there had been applications available previously, the adoption of these technologies was limited. The 1970s, however, saw a widespread implementation of computer systems with the capabilities of aiding both exploration and mining geology. These were the first established applications for computer software systems in the industry.

Once the software was commonplace, the development of its use in two applications proved to be particularly influential. Software to develop models for drill hole exploration and software to conduct operations researching an order to conceptualize and organize exploration.

Further to this, significant steps were made in the development of software systems that could analyse

data from minerals. Much research went into developing these applications, resulting in computer systems that could manage quite complex analysis. Also, developments were made in the areas of geochemistry and geophysics allowing for software capable of organization, display, and interpretation of this data.

By the early 2000s, there were already many software systems available to help integrate geological assessment alongside mine planning and design, and by 2005 software had the capability of generation of survey, assay databases, stratigraphy, drill hole and bench compositing, contouring, 3D surface generation, 2D and 3D log sectioning, cross-sectioning, 3D ore body modelling, designing of open pit, volume, and reserve estimation and economic valuation.

CURRENT SOFTWARE CAPABILITIES

Modern-day mining software has evolved to the point where it can offer mining companies game-changing capabilities. Spatial data visualization has been developed that can help mining workers gain insight on how to reduce operational costs and reduce their environmental impact. The advent of three-dimensional modelling enables workers to reimagine the mine more efficiently, highlighting interrelated issues. Virtual Reality has also been developed in this field, allowing users to plan a mine without being in the physical space. Also, augmented reality can be used to train new staff, and therefore reducing boarding costs.

Geographic information systems are another area of software development impacting the mining sector. It provides an essential tool with the capabilities of looking at how geographic relationships impact the world around us. With this technology, workers can solve real-life issues where the factors of location and accessibility are essential.

Artificial intelligence presents a large area of potential growth for mining companies. It supports the easy and fast location of minerals, as well as making operations safer and more cost-effective using autonomous vehicles and drills.

Software supporting the use of automated drones in the mining industry allows for the cost-effective and efficient completion of the following tasks: Safety and surveillance in hazardous areas, asset management, time-lapse photography, measuring stockpile inventory, infrastructure upkeep, and inspection and site mapping.

As digitization becomes more commonplace in mining companies, we can expect software capabilities to evolve further, and make operations more efficient, cost-effective, safe, and environmentally friendly.

The mining software market is highly competitive, owing to the continuous push for new developments in the field. Not only should the software companies respond to the needs of the end-users, but they should also focus on constantly developing mining solutions with high quality and improved functionality. In this extremely competitive market, contemporary software packages continue to introduce functionalities that are not available in other software packages. Mining software can only continue to evolve with the backing and drive of the end-users operating in the mining industry. Mining companies should look at software packages as a worthy investment and a tool that has been created to help simplify mining operations in a diverse number of ways.

FASTER DEVELOPMENTS IN COMPUTER HARDWARE AND OPERATING SYSTEMS

Computer hardware is emerging at a much faster rate as compared to computer software. Improved processors, quicker data buses, quicker and superior hard disks, and more advanced graphics systems allow users to plan mining operations more quickly and accurately. These advancements have simplified everything that used to be extreme in geological modelling and mine design. Also, the price of essential hardware is not a concern anymore, allowing even smaller best mining software companies to have well planned IT departments. Software development tools are more consistent nowadays, thereby enabling developers to create software that is of better quality and compatibility for the prevalent operating system platforms.

going for the commodities sector, it could not be any sooner.

“Ten years ago, these were dumb bits of equipment. If the computer in the office fell over, who cared? Now underground mines are full of optical fibre and bits of equipment that talk to one another,”

For one, IoT will assist in the predictive/preventative maintenance for mining vehicles, which has become increasingly important in recent times. Using sensors, companies will have the ability to monitor everything from fluid temperatures, engine speed, gear position and brake pressure. Information from the sensors will be relayed to a remote monitoring center that will then alert the equipment operator of potential trouble before it happens. The technology will provide data analytics of the truck performance data to prevent unnecessary maintenance events and to reduce the time to repair the truck during unplanned maintenance events.

Related content: Is the Internet of Things the next wave for the mining industry?

Like the film, IoT also has the ability to empower mining equipment to function and operate with optimal efficiency.

“Lots of these machines have been sending data for more than 30 years, but we did not have the ability to use it,” says Al Frese, solutions and technology manager for mining sales and support at Caterpillar. “Now we have that and can do it effectively across many different sites.”

US-based Caterpillar Inc. is a major player investing in the Internet of Things. Last year, the company spent $2.14 billion on product-oriented research and development alone.

Rob Charter, a group president at Caterpillar, has said that the company wants to surround customers with a tech-savvy suite of products and services. It is about moving beyond simply making machines, he is noted.

“Originally, when we built product, it was about the product,” Charter said. “What we think about all the time these days – and you'll see it more and more in people's thinking – is how do we make a customer successful? And if they are successful and they rely on us, then we're successful.”

SOFTWARE INTEGRATIONS

Neither the old-styled is an organized method to having inaccessible pockets of unhelpful automation nor the all-inclusive, expensive, organization-wide system that in several cases fails to bring the assured product before being surpassed by the next main advance in hardware are probable to achieve the anticipated result. Contemporary mine planning software solutions are more focused on functionality that is required and not outspread in areas that do not add much to the package’s value and are already covered by dedicated packages. In contrast, integrating functionality that is unswervingly linked to the mine planning procedure, like production arrangement and pit optimization, can be extremely helpful as it will upsurge productivity levels and allow simpler and quicker examination of different operational situations.

USAGE OF THE INTERNET

The Internet is a space where mine planning software gets the potential to grow in several diverse ways. Presently, it is being used for remote software licensing, data distribution and communication, troubleshooting bugs and technical support amongst software vendors and end-users, and distance learning. Software updates and demos, as well as other data, are offered by numerous vendors to the registered users of their software.

The Internet of Things is expected to ring in a new era for mining operations and equipment. With the way things are

Lubrication and challenges

Mining as an industry began many thousands of years ago, with the excavation of ores by hand, and has now evolved into modern day mining. Today, heavy-duty machinery can remove tonnes of ore, minerals, and other debris from the Earth every day. Lubricants have also advanced significantly over the last few decades and can now be used for long periods to help protect mechanical parts – an application of particular interest in the mining industry. In this article, we look at the use of lubricants in the mining industry and why it is beneficial.

The progressive development and upgrade of open gear lubricant design concepts have always been driven by machine manufacturers in response to customer demands for high production rates and improved equipment durability. The need for higher production rates impacted the machines in the form of increased loads and speeds, often resulting in machinery operating at or beyond its design capacity, which negatively impacted the demand for improved machine durability. As a result, the preferred properties of open gear lubricants (by OEMs) changed to develop lubricant-based solutions that catered to operational issues. This situation has never been more prevalent than it is today.

In recent years, some large lubricant marketers have run advertisements on TV that highlight the importance of viscosity breakdown. These advertisements make it seem like viscosity is a complex chemical property of the fluid, when in fact it is a measurement of a physical property.

Simply stated, viscosity is a measure of a fluid’s internal resistance to flow. A good example of this was provided in one of the TV ads, which showed two oils being cooled until one continued to flow out of the bottle readily, while the second dropped out in blobs. The resistance to flow, or viscosity, of the second oil had increased dramatically with the decrease in temperature. This ad illustrated just how important it is to consider viscosity when choosing the proper lubricant for a specific application. The presence of viscosity information on all lubricant marketers’ technical literature is an indication that it also is important in the marketing of lubricants.

Original equipment manufacturers often specify the lubricant to be used in their equipment by product type and viscosity. Lubricant marketers usually sell their lubricants according to specific viscosity grades, such as SAE 15W40, ISO 46 and AGMA 3. It is clear that – for most of the players in the lubricant industry – the proper viscosity of a fluid is the most important attribute in proper lubrication. There are several reasons for this, including, but not limited to:

- Viscosity affects fluid film thickness under certain conditions of temperature and load in lubrication applications.
- Viscosity affects heat generation and removal in bearings, cylinders, and gears.
- Viscosity determines the ease with which machines can be started in low-temperature conditions or can be kept running in high-temperature conditions.
- Viscosity can be used to control a fluid’s sealing ability, which results in lower consumption.

VISCOSITY DEFINED

As mentioned above, viscosity is a physical measurement of a fluid’s internal resistance to flow. Assume that a lubricating fluid is compressed between two flat plates, creating a film between the plates. Force is required to make the plates move or overcome the fluid’s film friction. This force is known as dynamic viscosity. Dynamic viscosity

is a measurement of a lubricant's internal friction, and it is usually reported in units called poise (P) or centipoise (1 P = 100 cP).

A common tool used to measure dynamic viscosity is the Brookfield viscometer, which employs a rotating spindle that experiences torque as it rotates against fluid friction. This test will be discussed in more detail later. A more familiar viscosity term is kinematic viscosity, which considers the fluid density as a quotient of the fluid's dynamic viscosity and is usually reported in stokes (St) or centistokes (1 St = 100 cSt). The kinematic viscosity is determined by using a capillary viscometer in which a fixed volume of fluid is passed through a small orifice at a controlled temperature under the influence of gravity. Grease viscosity, traditionally called consistency, cannot be measured using the tests noted above. However, it is still relevant for selection of the correct grease for a specific application. Greases are fluid lubricants enhanced with a thickener to make them semi-solid. They usually are used in applications where a liquid lubricant would run out. Greases are sold by consistency grade, which in this case will be used synonymously to viscosity grade. Grease consistency is measured using the cone penetration test. The National Lubricating Grease Institute (NLGI) created grade ranges for greases that have become the industry standard. These ranges characterize the flow properties of greases.

In mining, heavy-duty and high-temperature lubricants, hydraulic fluids, and multifunctional oils must resist high mechanical and thermal loads as well as the rough ambient conditions. The industry is continuously seeking improved lubricant solutions to each part of its operational requirement, specifically because it has a direct bearing on the wear and tear of the equipment, which in-turn impact the lifespan which impacts the profit margins. Apart from economic benefits, lubricants need to comply with special standards and safety regulations combined with eco-friendly considerations.

Reliable and cost-efficient lubrication under extreme conditions requires not only the use of high-performance lubricants, but also expert knowledge regarding their appropriate application. Lubricant manufacturers have continued to improve their products to meet the needs of bigger, faster machines. Although most lubricant suppliers are not lubrication system specialists, many have the resources to provide technical support, offering sound advice for selecting the products best suited for the applications.

The products commonly used in mining equipment can be divided into three groups: heavy-duty lubricating oils, such as EP oils for enclosed gear drives; multipurpose engine, circulating and hydraulic oils for engine, bearing lubrication and fluid power; and general-purpose grease, for normal industrial bearing applications and specialized mining products. Walking draglines may require lubricants for the very large plain bearings that support the entire frame of the unit as it moves through the walking process.

These lubricants may have a high concentration of lubricating solids or soft metals dispersed into a stiff grease and delivered in small bags (for the walking mechanism without an automatic delivery system) just ahead of the peak loading area. This grease is referred to as a Walking Cam lubricant.

An effort to reduce the number of lubricants on a machine has driven the development of multipurpose products designed to meet several different applications from a single lubrication system. The various components to be lubricated may include the open gears, guide rails, main table bearings and various smaller slides and bearings.

This presents a variety of challenges to tackle with one or two products. Specialty product manufacturers strive to meet the wide range of challenges with a single product.

More recently, independent lubrication service consultants are becoming a viable alternative to the industry. Utilizing an independent consultant offers a mine the ability to purchase the product of choice based strictly on quality and product cost, but without any possible hidden costs of product-service combinations or cost-per-hour contracts.

The operators purchase the lube products for the equipment based on equipment criteria and purchase the service of a consultant based on experience and costs. This platform is a unique and upfront approach to product-service combinations. When considering an independent lubrication service consultant, check the individual's references supporting his/her abilities and knowledge.

As the industry continues to evolve, expect to see continued evolution in all aspects of the industry and allied fields. With global positioning satellites (GPS) offering the potential for remotely operated equipment, computer systems taking lubrication systems to new levels of control, manufacturers continuing to meet the demands of an ever-changing and competitive industry, one thing should always remain the same.

When it comes to the development and application of lubricating products, providing the cleanest possible environment, storing the products properly, reducing rehandling and applying the right product – in the right amount, in the right place, at the right time – will always be the necessary criteria, no matter how many times these practices are reinvented.

LUBRICATION CHALLENGES

Each piece of mining equipment made by different original equipment manufacturers (OEMs) has its specific lubrication requirements. OEMs define the minimum requirements for lubricants or greases, but not all products that meet these standards deliver the same level of performance.

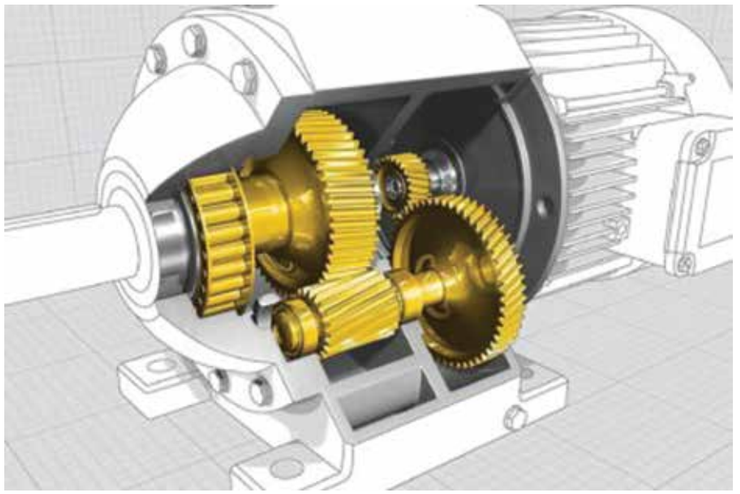
Choosing the correct lubricant or grease often depends on a combination of the equipment's design characteristics, operational parameters, and environment. Factors like temperature, humidity, and location (altitude/underground) all pose different challenges for lubrication. Below are three of the primary lubricant applications in the mining industry, along with some examples of specific lubrication challenges. In all cases, selecting the right lubricant is a critical first step in improving productivity and realising significant savings.

Effective engine lubrication is critical to protect high-cost equipment, and minimize downtime due to frequent oil changes, maintenance or even component failures.

VISCOSITY CONTROL IN EXTREME CONDITIONS:

Engine wear because of metal-to-metal contact can occur at low speeds, high loads, or cold starts. The lubricant helps keep moving parts separated to avoid wear. At engine start-up, particularly in cold climates, the oil must remain thin enough to circulate quickly to protect critical components. Once the engine is operating under full load, the oil needs to remain thick enough and provide the necessary protection to help prevent abrasive wear.

In gear motors, the lubricant must help improve bearing life and give excellent protection against wear and pitting. Transmission oil helps keep moving components apart, such as gear teeth and rolling elements, thereby avoiding metal-to-metal contact and wear. Selecting a product that has the optimal viscosity for the application, along with the required additives to protect against wear and corrosion can have a major impact on equipment life. Viscosity and shear stability are also critical for performance at a range of temperatures.



SOOT GENERATION:

Accumulation of soot in the engine can lead to oil thickening and abrasive wear. This is a particular challenge in underground mines, at high altitude, and when exhaust gas recirculation (EGR) is applied as an after-treatment system. Extended periods operating at idle load makes an engine susceptible to higher rates of soot generation.

CORROSION PROTECTION:

Gases and acids are generated as a natural by-product of the combustion process. The lubricant neutralises these acids to help avoid corrosion. This is particularly important in engines with Babbit-based plain bearings, which can be very susceptible to acid attack.

LONG OIL LIFE:

Oxidation, soot accumulation and oil thickening, and the build-up of acids in the lubricant all contribute to oil aging. High quality synthetic engine oils with the right base oil and additive technology -including antioxidant additives -can maintain performance characteristics for longer time in the presence of contaminants and by-products. Oxidation stability and corrosion protection are also important to maintain oil performance. High quality transmission and gear oils with good oxidation resistance can resist degradation and break-down over time, thereby reducing downtime required for frequent oil changes

FRICTION CHARACTERISTICS

Powershift transmissions use a series of friction plates to help engage and disengage gears. The lubricant plays a critical role in transmitting frictional force, so its frictional properties are important for effective operation. Too little friction, and the plates can slip making gear changes difficult. Too much friction and excess heat generation can cause damage to equipment and shortened lubricant life.

Lubrication by Grease application in the mining sector can be a specialist technical area, where selecting the right grease for the right application can be critical to avoid costly equipment failures and unplanned downtime. This is particularly true for open gear applications, which are exposed to the elements in extreme conditions, and where contamination poses a significant challenge.

WEAR PROTECTION IN SEVERE OPERATING CONDITIONS

Temperatures

As open gears are exposed in all climatic conditions, the grease's viscosity and pumpability is critical. In extreme cold, it must remain fluid enough to flow through grease lines to protect components, while in extreme heat it must remain thick and adhesive enough to stay on equipment surfaces.

Contamination

Contamination ingress is the direct cause of about 40% of open gear

failure. Exposure to high levels of dust, dirt, slurry, rain and snow means open gears require greases that can maintain an adequate lubricant film and continue to flow while flushing out contamination.

Pressure and shock

In differential gears, specific contact pressures can be so high that the transmission oil is squeezed away, allowing metal-to-metal contact. The use of extreme pressure additives helps prevent the contact areas of the teeth micro-welding together.

To help keep equipment operating at maximum efficiency, greases must be specially formulated to withstand the high load, extreme pressure, and shock-loading faced by mining machinery daily. Application – Misapplication is the cause of around 40% of open gear failure. Even a perfect lubricant cannot protect equipment if it is not applied in the right volume at the right time. Lubrication systems must be maintained and fine-tuned to ensure correct application happens.

Misalignment

Two perfectly aligned gears have a contact ratio of 100%. If misalignment causes the contact ratio to drop below 85%, the load and stress on the gearing will increase. This overloads the gears and the lubricant film and can result in sub-surface cracks and pitting, which significantly reduces component life and may result in gear failure.

THE SHIFT TO LONG-TERM LUBRICANTS

Longer lifetime lubricants are starting to be used more and more in many applications, with one of the biggest current adopters being the automotive industry. The shift from short-term lubricants to long-life lubricant systems is starting to show many benefits for mining companies as well, including a smaller environmental footprint, increase in productivity, reduction in maintenance, improved safety, and lower long-term cost.

The mining industry often suffers from water contamination issues because of spent lubricant entering water sources. The shift from short-term to long-life lubricants can help to reduce the levels of lubricant waste produced by a mine, which in turn can reduce the amount that leaches into the environment. Additionally, many long-term lubricants are designed to be more energy efficient which further reduces the impact on the environment.

Regarding productivity and maintenance, the more maintenance a piece of machinery requires, the greater its downtime. Over time this can add up, leading to a decrease in productivity. The switch to a long-lasting lubricant not only reduces the amount of maintenance required, but it also enables the mining company to take a predictive maintenance approach. Therefore, long-lasting lubricants reduce the need for maintenance, and as a result enhance the productivity of the machinery through longer operating times. Additionally, because many of the long-lasting lubricants are more advanced formulations, they can reduce the wear in a piece of machinery, again reducing the need for regular maintenance and keeping the machine in a better condition.

Many accidents that occur within the mining industry are due to the interactions between humans and machinery. Longer-lasting lubricants reduce the interactions required between human and machine, meaning mining employees spend less time in hazardous situations, increasing the safety of mining operations from an occupational perspective.

Finally, all the benefits mentioned above reduce the long-term costs of mining. Not only can long-lasting lubricants increase productivity, leading to greater profits, but they can also reduce costs through more energy efficient processes, reduced lubricant consumption and a reduction in maintenance and replacement machinery.

Electric rope shovels are the primary large earthmoving machines at open pit mines around the world. These machines are versatile, mobile, and very dependable.

Electric rope shovels, in combination with various support equipment, including large haul trucks, maintain a steady flow of product to the first stage of processing, namely the in-pit crusher.

During the past few years there has been a rash of premature severe wear and catastrophic failures in many shovels open gear applications around the world. In some cases, there has been evidence of scuffing, which suggests insufficient lubricant film thickness leading to metal-to-metal contact initiating severe wear. Often, a change to a more viscous lubricant to form a thicker lubricating film may arrest the problem. In some of these cases of premature wear and catastrophic failure, well respected gear engineers have identified misalignment as an underlying problem.

MONITOR OR WAIT FOR SHUTDOWN?

Some mining equipment manufacturers and mining companies do not monitor the mechanical health of their many shovels, choosing instead to wait for scheduled shutdown periods. One of the world's largest manufacturers of above-ground mining equipment, P&H Mining, has chosen to monitor the health of their shovels on a regular basis using vibration analysis. For some time, this was done using portable monitoring equipment, but recently they have begun to do it automatically.

WHY VIBRATION MONITORING IS USEFUL

A mining shovel is difficult to monitor because of its mechanical complexity. For this reason, vibration analysis tends to be the best technology to determine its health. Vibration sensors can be attached at the bearing locations on the shovel's complex gearboxes and motors, either for the duration of the test or put in place permanently. Analysis of the signals from the sensors can identify lubrication issues, early bearing defects, early gear defects, alignment issues, structural issues, manufacturing defects and more. With early detection of developing problems, maintenance actions can be planned with minimal production interruptions, and minor issues can be corrected before they become major faults. If the analysis indicates that a major component will soon need replacement, there is enough time to make plans and order the replacement before a failure occurs.

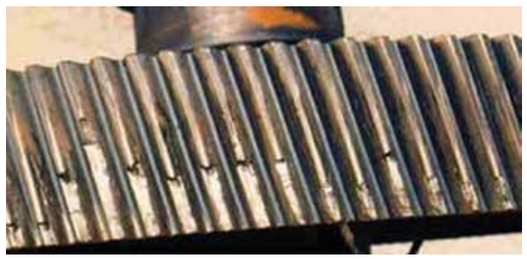
Electric rope shovels with capacities up to 100 tons are one of the most critical assets in open pit mines.

However, an electric rope shovel is not an easy application for vibration analysis. The shovels are variable-speed systems with short cycle times, complex gearing arrangements, and high background vibration levels − not to mention that they tend to be in some of the most remote places on the planet.

However, in most cases where premature wear and catastrophic failures have occurred, there is clear evidence of the gears operating beyond their capacity resulting in severe progressive macropitting, plastic flow and even tooth cracking and breakage. These modes of wear and failure are classic overload symptoms. In response to this situation, some OEMs changed their open gear lubricant specification to include a higher base oil viscosity requirement.

FIRST APPLICATION OF VIBRATION MONITORING

P&H Mining Equipment was the first shovel manufacturer to successfully apply predictive technologies and services to its electric rope shovels and other mining assets. This involved not only portable vibration analysis, but also infrared examination, lubricating oil analysis and ultrasonic testing.



From these service offerings grew the P&H MinePro service organisation. For the portable vibration analysis, MinePro used technology from Emerson Process Management's CSI Portable Technologies and Machinery Health Management (MHM) business, including PeakVueR analysis software. This is designed to pick out and identify the high-frequency components of a vibration signal, which provide early indications of developing bearing faults. These include inner and outer race defects, ball defects, lubrication problems and any type of "impacting" fault, where metal is contacting metal. PeakVue also provides early failure warning of those expensive gearbox components.

Vibration sensors are moved from point to point on various parts of the shovel and connected by portable data-gathering equipment; during which the shovel is then operated through a consistent sequence of motions of the swing, hoist, and crowd systems. This is done about once a month and involves taking the shovel out of production for two to four hours while it goes through simulated operation.

ADVANTAGES OF THE AUTOMATED APPROACH

Planned or not, a shutdown is still a shutdown and can cost up to a million US dollars. In addition, sending personnel to monitor the working parts of the shovel − which must be in motion during many parts of the data acquisition − raises safety concerns; for example, a common test procedure involves making the shovel rotate in a circle like a huge top for 20 minutes with two extra people on board to do the monitoring.

On top of this, simply planning for that monthly outage can be an enormous task, requiring coordination among the production people, the maintenance people, the on-site safety manager, and specialised personnel where needed. It is not unusual to have to wait two weeks to get a shutdown scheduled.

If a vibration monitoring system could be permanently mounted to the shovel and operate automatically it could gather information as the shovel is operating, with no shutdown. And it would not need to be scheduled in advance or coordinated with the production department.

With more than five decades of providing high performance lubricants and lubrication solutions to the mining industry, including high performance open gear lubricants, Bel-Ray, a New Jersey-based high performance lubricant manufacturer has developed an open gear lubricant that exceeds the state-of-the-art in open gear lubricant technology to date with

its Molylube Ultra Open Gear Lubricant. Molylube Ultra Open Gear Lubricant is formulated to provide maximum open gear protection even in overload and under design conditions.

Molylube Ultra Open Gear Lubricant is designed to minimise total cost of ownership of open gear sets by maximising component service life, machine availability and production rates. Most importantly, Molylube Ultra Open Gear Lubricant is designed to address critical electric rope shovel open gear durability issues that have been seen in recent years.

Bel-Ray lubricants have a reputation for being best in class when it comes

to quality, performance, and innovative technology. Mining machine lubrication requirements drive lubricant development. It is difficult to "think and act outside the lubricant box," when the basic machine design and operation remain inside the box. So, Bel-Ray just made the lubricant box bigger and better with the recent introduction of Molylube Ultra Open Gear Lubricant. Although the basic machine design and concept remains the same, demands on the equipment continuously change with increased loads and operating speeds feeding the need for increased machine production and availability.

A well-designed gear set, designed for its intended operating environment and operated within its design parameters, will last for a long time if well lubricated and maintained. Over the years, companies specialising in grinding mill girth gear and pinion lubrication, including Bel-Ray, have designed a program of lubrication that targets all the needs of the gear set, including priming, running-in and service or operation. This concept of mill gear lubrication has worked well for a long time; therefore, it is recommended for electric rope shovel operators to use it on their open gears to help reduce premature wear and catastrophic failure issues.

From new, a mechanical device follows a well-defined risk curve with the risks being wear and failure. The highest risk of failure is in the earliest stages of machine operation and as it approaches the end of its anticipated life. There are three key stages:

Early in life during priming and run-in or break-in. This is a critical time in a gear set's life. If run-in is not accomplished in a controlled way using a suitable lubricant, various forms of pitting can begin. A suitable lubricant will help to prevent this.

Every gear set must start life with a priming lubricant or pre coat to ensure protection at initial start-up followed by a running in surface treatment.

During the normal service or operational stage, if the correct lubricant is applied, very little wear will occur during normal operation. Critical aspects of the lubricant are of sufficient viscosity to keep tooth surfaces separated by a full fluid film and high load carrying capabilities to provide chemical protection if the lubricating film is disrupted.

End of anticipated life is an interesting concept. Anticipated life is what the design engineers have determined to be the operating life expectancy of the gear. Often, with a well-designed lubricant, the gear will operate well beyond its anticipated life. The opposite is also true. With a poorly designed lubricant or one that is not correctly applied, the gear will fail before reaching its anticipated life.

Achieving anticipated life can be difficult considering that the operation of these machines can frequently change. Environmental considerations such as ambient temperature, moisture, dust, and other contaminants will impact machine operation. Increased production requirements will make machine operation more demanding. Stresses on lubricants follow the same patterns as stresses on machines. The selection of a suitable lubricant that possesses all the necessary characteristics will positively affect meeting or exceeding anticipated component life.

	Leading Grease OGL	Leading Compound OGL	Molylube Ultra OGL
Last Non-Seizure Load, kg	100	80	160
Weld Load, kg	800	>1000	>1000
Scar Diameter@ 1000kg,mm		3.2	2.75
Load Wear Index, kg	154	156	223

With the degree and frequency of premature wear and catastrophic failure of electric rope shovel open gears seen around the world in recent years, lubricants and lubrication become more and more critical. Although there is no lubricant-based solution for gear tooth cracking, bending, plastic flow and breakage, a carefully designed, formulated, and correctly applied open gear lubricant will help to control issues such as scuffing and pitting. All the points and issues discussed in this brief article are directed at helping mining companies maximise production rates, machine availability and durability in an environment that frequently varies and is often detrimental to achieving these operational goals.

Heap leaching – an economical solution

Heap leaching is a low-cost technology used in industrial mining to recover precious metals such as gold and uranium, along with several other highly sought-after metals like copper, from their primary resources (ores and minerals). For many decades, there has been a growing demand for heap leaching due to its environmental benefits. Heap leaching provides mining operators with a benign, effective, and economical solution for the environment and produces only minor emissions from furnaces. The cost of the heap leaching process is low, making this process an attractive option from a financial standpoint.

Heap leaching is one of the oldest and the most traditional mining processes used to extract the valuable metals from specific minerals. Basically, this is a hydrometallurgical process in which the solution is applied for the dissolution of minerals from the ore that is used for the extraction of metals. Originally, heap leaching was practiced 500 years ago. Georgius Agricola published a book De Re Metallica in 1557 and reported that the heap leaching process was finished in a 40-day cycle.

Since the middle of the 16th century, heap leaching was practiced in Hungary for copper extraction. In 1969, gold heap leaching began in Nevada (birthplace of modern heap leaching) and in the middle of the 20th century, the United States Bureau of Mines began applying this technology. Gold and silver heap leaching first began at Cortez in 1969. Currently, 37 different heap leaching operations are active worldwide to produce gold, which is estimated to be around 198 tons per year.

Currently, new heap leaching operations are successfully commissioned throughout the world with the goal of treating mine tailings and residue and to establish effective waste management facilities. In recent years, 50 major heap-leaching, solvent-extraction, electro winning operations have been established throughout the world, and approximately three million tons of copper have been recovered, representing roughly 16% total copper production. The heap leaching technology developed thus far can be used for different types of ore. Advanced modelling studies and solid fundamentals of heap leaching technology could make the process more adaptable for increasingly composite ores.

Several factors are crucial for notable heap leaching operations, such as proper heap building and ore evaluations, efficient comminution methods, and feasible approaches to control the heap leaching process. There have been extensive reports and publications on current heap leach pad designs and construction practices. Current heap leaching methods were developed according to the industrial requirements. For example, heap leach ore depths were increased from 50-60 ft. to 500 ft. This function is significant for controlling the economic efficiency, surface area availability and for reducing the impact of mining reclamation on the environment. Heap leaching solution application rates are optimized for metal recovery with the minimal chemical consumption. The heap leaching process is very simple and thus offers greater economic feasibility over more expensive technologies. The motivation behind the use of heap leaching is financial feasibility.

The major advantage of the heap leaching method over conventional leaching and recovery techniques is that heap

leaching consumes less than 0.3 ton of water for one ton of ore. Tank leaching normally operates as a continuous process within specially designed reactors. This approach is also known as a semi-closed system. Essentially, tank leaching is carried out in a set of tanks. In pressure leaching, finely ground ores are chemically treated at high pressures and temperatures within the reactors. The foremost application of the tank leaching method is the extraction of aluminium at low pressures and temperatures [9].The heap leaching process is obviously suitable method and has lot of advantages as mentioned above: however, as per the environmental concern it has some draw backs, such as time consumption, water loss, accidental leakages of pregnant leach solutions, slow heap leach kinetics, and acid mine drainage problems (sulphide's).The objectives of this article are to provide information on the applications of a unique and versatile heap leaching process for rare earth extraction and to highlight the advantages and limitations of this process.

HEAP LEACHING OF MINES

Industrial mining processes are the activities involved in the extraction of metals or minerals. A good example can be the classical production process of iron sulphate. In this process, iron pyrite was heaped up and the leachate coming from the heap was collected and boiled with iron resulting in the production of iron sulphate. The basic processes involved in heap leaching are ore crushing, spreading the crushed ore over HDPE or PVC geomembrane-lined pads, and spraying a leaching solvent like sulfuric acid or cyanide over the pads so that valuable minerals will dissolve into the pregnant solution. Metal recovery is then performed through precipitation, smelting or electro-winning and absorption methods.

Generally, low-grade ores of valuable metals like gold, silver, and platinum are mined from the surface of the earth or sometimes subsurface of the earth, pulverized into tiny particles, and collected on to a dense leach pad. The heap leaching process involves several steps. First, a leach solution is used to irrigate the heap. The second step is interaction with the ore particles. Third, the precious metal leaches out of the solution. Fourth, the pregnant solution is collected, and finally, draining of the tailing areas is done for metal extraction. Lime, Portland cement, coal fly ash, and bottom ash, or other materials are mixed with crushed ore for agglomeration. In a few cases, after pulverization, sulphide ores can be treated via chlorination, bio-oxidation, roasting and autoclaving methods prior to the heap leaching process. In gold leaching, two similar types of leaching pads are used to maintain permanent heap operations. A summary of leaching methods used for the extraction of various metals is shown in **Table 1**.

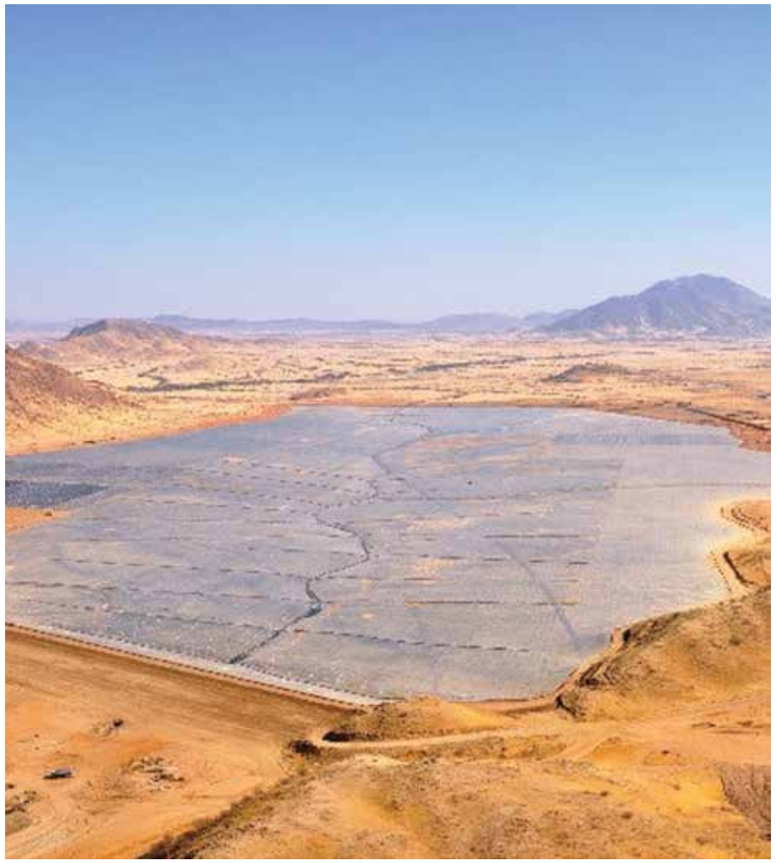
Precious metal recovery by heap leaching, base metals from oxide ores, Zn, and gold recovery by heap bio oxidation. The main concern of this thesis was to understand the gold mineralizing process and the optimization of operational parameters during the bio-oxidation process. Basically, the low-grade ore was oxidized via the biological heap method, and later it was utilized as a supplementary feed. The heap leaching with computation process is a newly developed heap leaching methodology that combines analytical modelling and the Bernoulli type model to achieve a heap leaching scale up process. This method is very useful to optimize the heap leaching process (design, analysis, control and optimization) and also proposes optimal flow rates for the heap leaching process of gold, platinum group metals and base metals sequential heap leaching for platinum group metals, heap leaching with mathematical

Table 1: Summary of leaching methods for the extraction of different metals with recovery efficiencies.

Method	Extraction Metal	Summary	Reference
Heap leaching	Precious metals from mineral fines	Leaching has been used principally in connection with low-grade copper ores or pit wastes	Michael Kerr *et al*., 1998
Heap leaching	Base metals from oxide ores	75-82% of Nickel recovery was achieved in 160 days to 266 days, 90% Cobalt recovery was achieved in 14 days, Iron recovery (53.6%) was achieved in 198 days at ambient temperatures	Anthony *et al*., 2004
Heap leaching	Zn (Zinc)	The 95% of zinc recovery was possible in 16 days cycle at 25C by column (heap) leaching.	Wen-qing *et al*., 2007
Heap leaching bio oxidation	Gold	49-61% of gold was recovery by bio oxidation process at 81C. The bio oxidation process was for gold recovery was taken 150 days.	Wes K. Sherlock 2010
Heap leaching with computation process	Copper	71-73.5% of copper was recovery by developed a new heap leaching methodology with the combining analytical modelling at optimal flow rates.	Mario E. Mellado *et al*., 2011
Heap Leaching	Gold	30-95% of gold was recovery by best available technology heap leaching compared to other techniques.	Caner Zanbak., 2012
Heap leaching	Platinum group metals (PGMs) and base metals (BMs) from a low grade flotation concentrate of PGM concentrator plants.	The extractions of 52% Cu, 95% Ni and 85% Co were achieved in 30 days (65C) by heap bioleach. If cyanide leach process (23C) can be operated in 21 days, 20.3% Pt, 87% Pd and 46% Rh, if 50 days or more to achieve 50% platinum.	Mwase *et al*., 2012
Sequential heap leaching	Platinum group metals and particularly for palladium	At 65 C, 93% Copper, 75% Ni and 53% Co extracted by bio heap leaching in the 304 days. By cyanide leach experiment, 57.8% Pt, 99.7% Pd and 90.3% Au was extracted at 50C in 60 days.	Mwase *et al*., 2014
Heap leaching with mathematical modeling	copper	By the Mellado *et al*., method for the optimal design of heap leaching, 53-56% copper recovery was possible in a 61-67 days.	Jorcy Y. Trujillo *et al*., 2014
Heap bioleaching	Cu, metal extracted from reduced inorganic sulfur compounds.	Over 60% of Cu, extraction was possible by bio heap leaching at 45 C during the 30-48 days.	Watling *et al*., 2015
Heap leaching	Copper from ore	73% of Cu recovery was achieved in 140 days at 25 C.	Rautenbach, 2015
Heap leaching for rare earths extraction	Heavy rare earths and Yttrium	91.3% and 87.2% of Yttrium and dysprosium achieved by heap leaching for 60 days, respectively, at room temperatures.	Pingitore Nicholas *et al*., 2016
Heap leaching with increasing flux rate	Gold	73-87% of gold extraction was achieved by using heap leach process with increasing flux rate in the 40 to 60 days.	Ngantung, 2017
Heap leaching with the new model (MINLP) and GAMS software	Copper	69.7-76.7% of copper recovery was obtained from 19.5-43.5 days with the new mathematical modeling named mixed integer nonlinear programming (MINLP) including GAMS software (general algebraic modeling system).	Isis F. Hernández *et al*., 2017
Heap bioleaching	Nickel	60% recovery of nickel from the tailings for 110 days.	Anton Svetlov *et al*., 2017
Heap leaching with computational fluid dynamics model	Copper	55% of copper was recovered in the 700 days cycle at the temperatures from 12-45C.	Diane McBride *et al*., 2018

modelling for the extraction of copper was developed. In this paper, the authors reported the heap leaching plan and design for copper leaching by the mathematical model named MINLP and BARON-GAMS solver. They studied different primary variables such as acid price, variable costs, and ore grade quality. These were highly effective on the production capacity of copper.

It is possible to recover 60% of copper through heap bioleaching. The authors discussed an appropriate pad design for high leaching efficiency in the brief reviews on the heap pad designing criteria, pad characterization program, pad types, operational kinetics, material handling, and risk assessments. Finally, the authors concluded and recommended some technical tips for successful heap leaching facilities. Cu recovery of 73% was achieved in 140 days at 25°C. In 60 days, 91.3% and 87.2% of Yttrium and dysprosium were achieved by heap leaching, respectively, at room temperatures. The leaching processes with increasing flux rate for the gold recovery were also reported.



Some brief reviews reported on the heap leaching of copper and gold. The main objective of this exclusive review paper is to understand the fundamental mechanism of the heap leaching process, as well the theoretical background of different heap leaching processes, global trend of commercial heap leaching operations, challenges, and the innovations and future directions of these process developments. This process is obviously suitable for low grade ores even if it has some draw backs. But it requires some comprehensive engineering concept developments for the higher efficiency of the product by heap leaching. Another brief review paper addressed a key technology for the recovery of valuable metals from low grade ores. The author covered heap leaching benefits, technical draw backs, economic feasibility, leaching kinetics, and environmental concerns.

Heap leaching with the new model (MINLP) and GAMS software, as well as the new model named mixed integer nonlinear programming (MINLP) including GAMS software (general algebraic modelling system) were utilized for the study of heap design and operational variables for metal recovery. It is one kind of a mathematical modelling applied for the copper leaching system. Recently, a heap bioleaching process was developed in Russia for the recovery of valuable copper and nickel from low-grade ore with a less expensive cost. In Russia, the Murmansk region required urgent research action for the mining wastes. In this region they developed the technology for the recovery of valuable copper and nickel from low-grade ore. During these mining activities, lots of wastes were deposited, so bio heap leaching technology was developed for the recovery of metals from ores with less expensive cost. Heap leaching with the computational fluid dynamics (CFD) model can analyse the heap design, operational parameters, optimization analysis and environmental conditions etc.

In the heap leaching process, initially the ore is pulverized and accumulated before it is placed on the heap to increase the mobility of the heap, as well as to maintain a high pH. Agglomeration involves the merging of the pulverized ore with binding material like ash, lime, Portland cement, or other materials. In few cases, pre-treatment of sulphide ores by bio-oxidation, autoclaving, roasting, or chlorination before heap leaching. There are two kinds of pad that are used in gold heap leaching, depending on whether the spent ore is removed or not: permanent heap construction on a pad and on-off pads. The former is the one which the leached ore is not removed from the pad and the latter has been where the spent ore is removed, and another fresh ore is allowed to be placed on.

Heap Leaching Advantages and Economic factors

Heap leaching has several advantages and economic benefits. These include low capital requirements and low operating costs [1]; the absence of a milling step for crushing and agglomeration; the simplicity of atmospheric leaching; possible use for the treatment of moderate (medium) grade ores, (pebble size is ~31 mm with round shape), wastes and few deposits; and omission of liquid-solid separation step for counter-current operations, when metal tensor can do accumulate due to the use of the recycling solution over the heaps. Some ores which require crushing, agglomeration, and conveyor stacking may require little additional cost. The capital expenditures (CAPEX) and operating expenses (OPEX) of copper, gold, and silver by heap leaching, tank leaching of copper, gold, and silver and autoclave leaching of copper, gold, and silver are expressed in million dollars per ton of ore in **Table 2**.

Heap Leaching of gold and silver

Heap leaching is a very significant and common process in the copper and gold industry. It is very economical and useful for treating a wide range of low-grade ore bodies on a large

Table 2: Comparison of capital expenditures (CAPEX) and operating expenses (OPEX) of copper, gold, and silver by heap leaching, tank leaching and autoclave methods.

Metal name	Heap Leaching Capital Expenditure (CAPEX) US$/t ore	Heap Leaching Operating Expenditure (OPEX) US$/t ore	Tank Leaching Capital Expenditure (CAPEX) US$/t ore	Tank Leaching Operating Expenditure (OPEX) US$/t ore	Autoclave Leaching Capital Expenditure (CAPEX) US$/t ore	Autoclave Leaching Operating Expenditure (OPEX) US$/t ore
Copper	29.5	4.6	25	66	75	19
Gold	22	4.51	40.9	22.28	492	8.20
Silver	22.50	14.87	40.9	35.96	17.40	82

scale. The simple heap leaching process is very competitive with other expensive laterite technologies. The Bureau of Mines reported the development of a gold ore heap leaching process which used a diluted cyanide solution for the gold and silver recovery from pregnant effluents by a carbon adsorption-desorption process. Hazardous waste engineering research laboratories submitted a report to the Environmental Protection Agency in the USA describing the great distribution and operational capabilities of the gold/silver heap leaching process and the potential environmental impact and management practices to minimize potential environmental releases. The basic processes involved in heap leaching are crushing the ore, spreading the crushed ore over HDPE or PVC geomembrane-lined pads, spraying leaching solvent like sulphuric acid or cyanide over the pads and then valuable minerals will dissolve into the pregnant solution. Metal recovery is then performed through precipitation, smelting or electro-winning and absorption methods. **Figure 1** shows a flow chart of a gold heap leach operation. A hydrometallurgical process has been designed for the amenable gold heap leaching from low-grade gold ore.

Heap Leaching of Copper

There are numerous reports available on copper heap leaching from copper ore. Some researchers have used heap leaching technology for the recovery of copper by using sodium nitrate as an oxidizing agent. The pH of the heap was maintained at pH < 1.7. Other investigations reported the heap leaching process of copper from diesel deposits. The non-ionic surfactant EVD61549 (a wetting agent) was used to increase the copper heap leaching efficiency. Heap leaching of waste copper ores from Volkovskoe deposits has also been considered for sulphuric acid leaching (25-75 kg/t ore). Over a period of three months, the copper leaching efficiency reached 76-78% overall. The copper recovery efficiency increased with an increase in the leaching time.

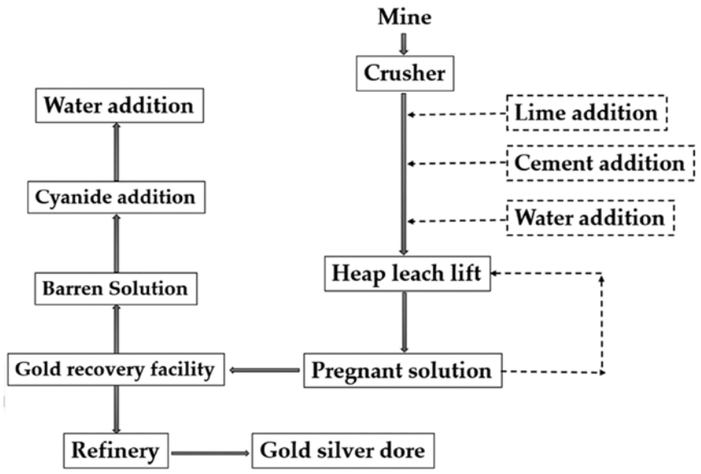


Figure 1: Chart of a gold heap-leach operation (adopted and modified from the reference 43).

Heap Leaching of Uranium

Large-scale uranium heap leaching activities have operated since the 1970s and 1980s. Historically, sources of uranium ore contain ≥0.05% of uranium/thorium. In the 1950s and 1960s, ores containing less than 0.05% uranium were periodically refined in small heaps. There are three methods used for uranium recovery, namely: traditional milling, in situ recovery (ISR), and heap leaching methods. In the USA, heap leaching technology is widely used for the recovery of uranium. A rancher exploration and development corporation in Colorado was operated between 1977 and 1979. Some investigations reported bacterial leaching processes. Generally, problems arose during the oxidation of U+4 species, and approximately 70% could be recovered. Heap leaching technologies eliminate grinding, tank leaching and the solid/liquid separation step, and it is likely applicable to many types of low-grade uranium ore of many types. The conventional leach times are between one and six months. Recently, researchers reported the analytical models for the heap leaching by global sensitivity analysis and uncertainty analysis. **Figure 2** shows a flow diagram of gold, copper and uranium heap leach operation flow sheets.

RARE EARTH ELEMENTS RECOVERY BY HEAP LEACHING

Recently, rare earth appliances are significantly increased for new products. During the past 20 years, REEs have many new applications such as clean energy, petroleum refining, electronics, and automobiles. Military applications have also arisen as these materials are widely used in communication systems, avionics, lasers, precision-guided munitions, radar systems, satellites and night vision equipment (**Figure 3**).

The assessment and source of REEs are in much interest, and advanced technologies

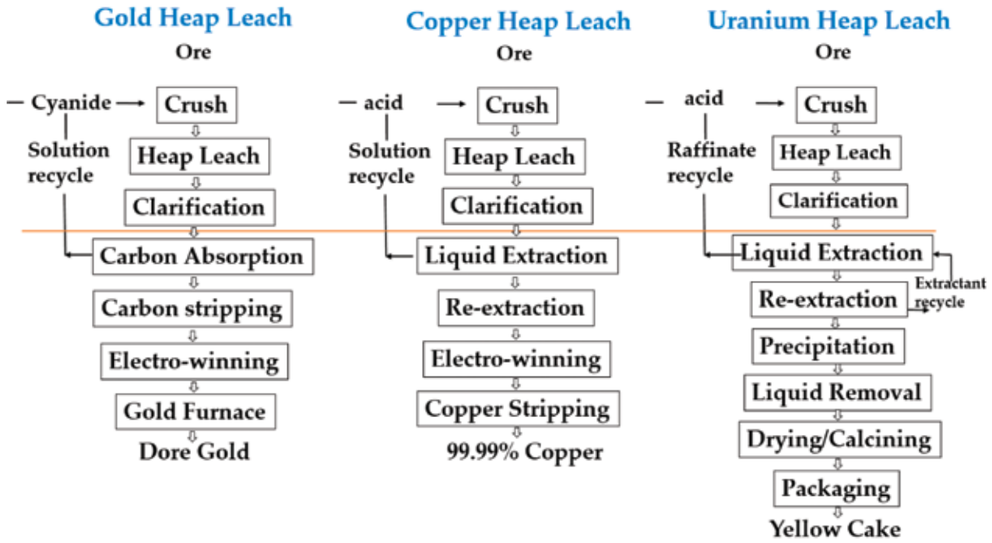


Figure 2:.Flow diagrams of heap leaching processes of gold, copper, and uranium (adopted and modified from reference 54).

Figure 3:.Heap leaching for rare earth recovery.

are therefore required for the recovery of critical rare earths from waste residue via the heap leaching process. In the second generation of leaching technology, heap leaching with (NH4)2SO4 in the early 1980s was used to enhance the product purity to more than 92% for the total rare earth oxide content. During the washing process, the solid-to-liquid ratio was maintained at approximately 0.6:1 build upon the leaching time and heap size. Leaching times ranging from 100 to 320 h are more beneficial for rare earth extraction, with rates up to 90% realized.

Ion-adsorption clays from various origins or ores are rich sources of rare earths and the recovery process by in-situ leaching and heap leaching. 80% of the rare earths such as Y, Nd, Eu, Tb, and Dy were recovered by several process including physical separation, bio-oxidation, heap leaching, precipitation, and solvent extraction respectively. In 250 days, 85% of there're earths were leached with pH 0. When pH was increased to 3, rare earth recovery was observed to increase by two-fold. Texas rare earth resources independently confirmed a 79.9% recovery rate by the heap leaching process. Recently, heap leaching was applied for the recovery of the yttrium, from the ore yttrofluorite. Yttrium-bearing fluorite at Round Top Mountain is a rich source of Yttrium, and other heavy rare earth elements were recovered by the heap leaching process. In 60 days, 91.3% and 87.2% of Yttrium and dysprosium were achieved by heap leaching, respectively, at room temperatures.

Recently, the National Energy Technology Laboratory (NETL) funded the University of Utah and Virginia Technology for the extraction of rare earths from coal refuse by heap leaching, along with other sequential processes such as coal processing, bio oxidation, solution treatment, solvent extraction, and precipitation technologies respectively.

CONCLUSIONS

Heap leaching technologies have been profitably adopted for the recovery of highly sought-after metals. Worldwide, a huge interest in heap leaching projects has-been observed for the recovery of precious metals. Heap leaching is an essential metallurgical process which has demonstrated a strong potential to reduce costs and liberate metals from challenging deposits. Nowadays, prices for all precious metals and rare earths are increasing rapidly due to the continuous demand in green technology applications. Heap leaching is a more economic process than any other conventional method, and exceptionally so for the recovery of precious metals from low grade ore.

AUTHOR CONTRIBUTIONS

T.T., R.C., L.H., and L.Q.T collected the information, summarized, and wrote the manuscript. C.H.K. corrected the final manuscript and agreed to submit this data to the sustainability journal.

Reducing groundwater nitrates through improved explosives selection and use

Mines, especially coal mines, in North America are subject to strict water quality discharge metrics, as well as being held to groundwater quality compliance monitoring. This monitoring means limiting the concentrations of several environmental pollutants such as sulphates, selenium, other heavy metals and nitrates in the effluents.

When compared to farming and sewage works, mines have a minor impact on groundwater quality as it relates to nitrates, but it stands to reason that the use of Ammonium Nitrate (AN) based explosives in blasting operations can have some environmental impact at a mine site level. It is incumbent upon mine operations to ensure they choose, and use explosives, in the most environmentally sensitive manner possible, in order to maintain both their social and regulatory Licenses to Operate.

During the blasting process, explosives that undergo a full order, oxygen-balanced, detonation create only three chemicals as a result – water, carbon dioxide and nitrogen – which dissipate into the air after the blast. If the explosives choice and use were to lead to nitrates leaching into the groundwater, the cause can be attributed to fully or partially undetonated bulk explosives product that has been washed (or leached) from the ground by water. A 2006 study by Golder Associates[1] at a surface diamond mine found that up to 8% of the explosives used were either wasted or incompletely detonated, contributing to nitrates leaching into the groundwater.

SOURCES OF FUME AND NITRATE LEACHING WHEN BLASTING

There are a number of potential sources of nitrate leaching when blasting, they include:

1. Design of transfers of Ammonium Nitrate at the site depot to ensure spillages can be cleaned up easily and that storage is not affected by rainfall

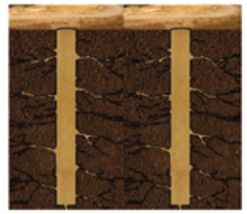
2. Unused product left on the bench as a result of poor bench housekeeping; when explosives are spilled around the borehole, or when excess product is discharged on the bench.

3. Using explosives that are insufficiently water resistant in wet ground, particularly ground with flowing, or dynamic, water. The longer such products are left, or “slept” in wet ground conditions, or the more dynamic the water flow is, the more leaching will take place. The overall quantity of explosives that are insufficiently water resistant, in wet ground, will also have a direct impact on the amount of leaching.

Sources of Nitrates in Mining

MINE OPERATIONS | MAIN CONTRIBUTORS

- **Explosives usage**. Water resistance level, sleep time, explosive quality and quantities.
- **Water conditions.** The amount of water getting into contact with explosives is decisive to the transportation of nitrogen into waterways: dynamic vs static water
- **Explosives management.** Losses and spillage of explosives may take place during storage of Ammonium Nitrate raw materials, filling of explosives loading equipment, actual loading of blastholes, spillage on bench and disposal of excess product.
- **Efficiency of the blasting operations** will control the amount of undetonated explosives and the amount nitrogen available in these. Failures may happen e.g. by poor design or execution, fractured ground, poor loading practice, explosive quality, stemming, washout. NOx fume.
- **Other sources**: Nitrogen content from rocks



4. Poor on bench practices in hole loading, for example top loading a wet hole through water, or poor hose retraction leading to water entrapment in the product and poor detonation through parts of the borehole

5. Product failing to detonate, or detonating incompletely, due to being at or below the critical diameter; **Figure 1** shows that blasting in fractured or seamy ground will lead to some of the explosives migrating into cracks and fissures with a diameter (or width) less than the critical diameter and thus remaining in the muckpile after the blast.

Figure 1: Fractured ground after blasting

6. Product being “dead-pressed” (due to dynamic pre-compression) above the density to detonate completely due to poor blast design such as incorrect pattern size in weak geology or inappropriate initiation system timing between holes and rows.

7. Improper explosives truck operation whereby the product is loaded with the wrong density or incorrectly mixed.

8. Product contaminated by stemming. This can occur when loaded explosives mix with the stemming material, or emulsion blends are loaded from the top of the hole (rather than pumped in from the bottom) and cling to the sides of the blasthole.

Interestingly, these sources of nitrates are the same sources that generally contribute to nitrous oxide (orange) post-blast fumes being generated during blasting, an outcome that can also lead to License to Operate issues for a mine operator.

FUME AND NITRATE LEACHING RISK REDUCTION PROGRAM

Over the years, Orica has developed a comprehensive risk reduction program that helps mining companies reduce both fume and nitrate leaching.

The first step in the program is to engage with the customer when notified of the problem with a bench top self-assessment to identify any specific key issues. As part of our commitment to excellent product stewardship, Orica will dispatch explosives experts to the customer site to begin the second step – a detailed site audit of the blasting operation starting with an assessment of the geology and ground conditions, followed by a review of the drill pattern, explosives product selection and the blast initiation timing employed. In addition, an audit of the site depot and blasting procedures will be undertaken, reviewing the “hygiene” and housekeeping practices of the blast crew as they load the

Figure 2: Increased clinging of explosives on a blasthole wall as the percentage of emulsion in the blend increases.

holes and the mobile manufacturing units as they load the equipment.

From the site audit, Orica will work with the customer to define, from the possible sources of nitrates and/or fume, what steps need to be taken to mitigate or resolve the problems.

I feel we have covered the potential sources above, do we need to repeat them again here. Or do we only do a high level in the top section (like in the presentation) and then dive into more detail here in what the outcomes might be from the audit. Working through the list of sources of nitrates outlined above, some or all of the following proposals could be offered to reduce both fume and nitrate leaching:

1. **Improved bench housekeeping.** This is one of the easiest places to start as care when loading explosives should be an expectation of any blast crew. Ensuring that product augered or pumped down a hole is confined to that hole is mostly a matter of allowing the team to work systematically, not speedily – taking time to properly position the loading equipment and making sure that excess product in the hose or auger is used appropriately down a hole rather than dumped on the surface.

2. **Explosives water resistance.** All manufacturers of explosives can provide data showing the relative water resistance of their products. Mine geologists can provide information about regions within the mine that have wet ground conditions, whether that be static or dynamic. Choosing explosives products that have the appropriate level of water resistance can follow. There is also a procedural element to this solution; ensuring that blast crews do not “dry out” a hole by loading Ammonium Nitrate Fueled Oil (ANFO) into a hole with some water at the bottom. This practice leads to dissolved and a non-explosive product at the bottom of the hole, exactly where the primer is. This can lead to misfires and large amounts of undetonated explosives in the muckpile; a clear source of nitrates available to be leached into the groundwater.

3. **Critical diameter.** In fractured ground it is important to use an explosives product with high viscosity which slows or limits the possibility that product will flow into cracks or fissures and remain undetonated after the blast. Certain higher viscosity products can also be gassed to a lower density while maintaining a high relative bulk strength. Thus, overall, relatively less product is put into the ground which will reduce the possibility for higher nitrate levels. Another way of accomplishing this is to use a plastic hole liner that encases the explosives inside the hole. However, this technique can lead to changes in how the explosives detonate (due to the additional fuel from the plastic), adding to the time taken to load each hole and, if torn, can lead to water contaminating the explosives products and subsequent misfires.

4. **Eliminating “dead pressing”.** This is an important step that needs to be accomplished when designing the blast: understanding the geology of the bench, particularly changes in hardness or lithology across the blast before designing the drill pattern (burdens and spacings) and the explosives load per hole. The key here is to ensure that the dynamic pressures radiating from each hole as it detonates is attenuated sufficiently before encountering upcoming undetonated holes. Failure to do so can lead to the explosives being compressed such that their density increases beyond the point of its ability to detonate. This will lead to misfires and, again, undetonated product being left in the muckpile, not to mention the resulting poor fragmentation and movement of the blast.

5. **Improved explosives loading truck operation.** Having a well maintained and well calibrated explosives delivery truck is paramount to ensuring that products delivered down the blasthole have the correct oxygen balance, the correct density, and the correct sensitivity in order to perform as designed. A straightforward way to check that this is occurring is to do a Velocity of Detonation (VOD) test and compare the in-situ VODs against the design specifications. Some mines will have this test highlighted as a contractual obligation of their explosives’ provider.

6. **Stemming contamination.** Another good practice during explosives loading is to insert a barrier or cap (sometimes called a “witch’s hat” or stemming plug) between the explosives and the stemming. When stemming migrates into the explosives, the resultant contamination can lead to undetonated product (and poor fragmentation) in the stemming zone, again leading to nitrates in the muckpile. Another source of nitrates in this zone can occur if pumped product is top loaded. Emulsion blends should always be loaded from the bottom of the hole so that the explosives rise can be measured (so the hole is not overloaded) and to ensure product does not bridge or cause a discontinuity, resulting in misfires, in the explosives column.

Beyond the procedural, or housekeeping, practices noted, choice of explosives is the most effective step a mine can take to mitigate against nitrate leaching into groundwater. Orica has developed a range of emulsion-based products that are specifically designed to provide the appropriate levels of water resistance, density, and viscosity to meet the range of ground conditions encountered by surface mining operators. When used in concert with data from “smart drills” (that can provide real time rock hardness/lithology metrics) and advanced blast design software through the BlastIQ™ blast optimisation system, Orica can provide the equipment and services that will tailor the explosives specifications to maximize blasting performance while minimizing blasting costs and minimizing the issues caused by nitrates leaching into the mine’s groundwater.

Orica has made great strides in the development of explosives and delivery technologies to minimize undetonated explosives and thus, nitrate residual. In 2019, Orica developed Fortis™ Protect, a thicker emulsion chemistry that can be thickened further through our explosive delivery MMU™ (mobile manufacturing unit) to the blasthole. While maintaining the capability to blend the emulsion with AN prill, this system provides a robust solution to minimize seepage into cracks and crevices while delivering the right blast outcomes.

With our 140 years understanding and advancements in explosives chemistry and delivery technology, Orica is providing the technical know-how and effective solutions to reduce nitrate leaching so that our customers can operate within environmentally safe guidelines and achieve high levels of operational productivity.

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Advancements in underground gas testing

An underground mining operation proves to be a risky venture as far as the safety and health of workers are concerned. These risks are due to different techniques used for extracting different minerals. The deeper the mine, the greater is the risk. These safety issues are of grave concern especially in case of coal industries. Thus, safety of workers should always be of major consideration in any form of mining, whether it is coal or any other minerals. Underground coal mining involves a higher risk than open pit mining due to the problems of ventilation and potential for collapse. However, the utilization of heavy machinery and the methods performed during excavations result into safety risks in all types of mining. Modern mines often implement several safety procedures, education and training for workers, health, and safety standards, which lead to substantial improvements in safety, level both in opencast and underground mining.

A worker in a mine should be able to work under conditions which are safe and healthy for his body. At the same time the environmental conditions should be such as will not impair his working efficiency. This is possible if mine air is nearly the same as on the surface without toxic and inflammable gases.

The gases are the present in the underground mines are flammable gas (CH4), Noxious gases (NO2, NO3, N2O5), Carbon Monoxide (CO), Carbon Dioxide (CO2). Hydrogen Sulphide (H2S), Sulphur Dioxide (SO2). The permissible limit set for these gases are as follows:

- Underground air should not have more than 0.5% CO2 or other noxious gases.
- Inflammable gas should be below 0.75% in the general body of return air and below 1.25% at any place in the mine.
- The general air on road must not normally contain more than 0.005% of CO[1].

Different gases that are present in the mine have different effects on the human body and can also cause explosion if reaches above a certain limit. The effects of some of the harmful gases are as follows:

- Carbon Dioxide on 3% (breathing gets doubled), 6% (headache, exhaustion), 15 %(consciousness loss), 25% (death after hours).

Table 4: (In this table the sources and the explosives limits of the common gases that are found in the mine are shown)[4]

Name	Primary sources in mines	Hazards	Flammability limits in air (%)
Methane (CH4)	Strata	Explosive, Breathing problem	5 to 15
Carbon dioxide (CO2)	Oxidation of carbon, fires, explosions	Increased heart rate and breathing	N/A
Carbon monoxide (CO)	Fires, Explosions, blasting, incomplete combustion of carbon compounds	Highly toxic, Explosive	12.5 to 74.2
Sulphur dioxide (SO2)	Oxidation of Sulphides, acid water on sulphide ores	Toxic, irritant to eyes, Throat, and lungs	N/A
Nitrogen dioxide (NO2)	IC engines, blasting, fumes, welding	Toxic, Throat and lung infections	N/A
Hydrogen Sulphide (H2S)	Acid water on sulphides, Strata decomposition of organic materials	Highly Toxic, irritant to eyes and explosive	4.3 to 45.5

- Carbon Monoxide on 0.02 %(headache, discomfort), 0.12 %(palpitations after 10 minutes of work), 0.2% (unconsciousness after 10 minutes of work), 0.5%-1.0% (death after 10-15 minutes of work).
- Methane This is the gas which is responsible for most of the underground mine explosions. It forms a layer just below the roof of the mine. The gas is not poisonous but can suffocate a person due to lack of oxygen[2].

ADVANCEMENTS IN UNDERGROUND GAS TESTING

Detection by warm blooded birds

In the earlier days for the gas detection the warm-blooded birds like munia were commonly used as they as they are affected much earlier than man by CO. such birds form essential equipment for the rescue party entering the mines after an explosion or fire. With 0.15% of CO present in the air a bird shows distress (ruffing of feathers, pronounced chirping and loss of liveliness) in 3 minutes and fall of the perch in 18 minutes. With 0.3% CO the bird shows almost immediate distress and fall of its perch in 2-3 minutes. Immediate signs of distress are not likely to be observed on birds when exposed to only 0.1% CO.

Coal has always been the primary resource of energy in India, which has significantly contributed to the rapid industrial development of the country. About 70% of the power generation is dependent on it. Thus, the importance of coal in energy sector is indispensable. But the production brings with it the other by-products, which proves to be a potential threat to the environment and the people associated with it. Present work is a sincere attempt in analysing the graveness and designing a Gas Monitoring system of detection by using the Zigbee technology.

A wired communication system inside underground mines is not effective, efficient, economic, and reliable. Due to unexpected roof fall at any moment the entire communication system of the total network may collapse. Effective communication is critical to the success of response and rescue operations; however, unreliable operation of communication systems in high-stress environments is a significant obstacle to achieving this. To improve security, protection and productivity in underground mines, a consistent communication system must be established between personnel, working in the premises of underground mine, and the control room. A wireless communication system is must for the safety point of view of the personal working inside the underground mines. Therefore, a fast, accurate, flexible, and reliable Zigbee Wireless network technology is used in our work[3].

The key issue of research on wireless sensor networks is to balance the energy costs across the whole network and to enhance the robustness to extend the survival time of the whole sensor network. Zigbee technology is given

Munia bird as a part of search rescue team of a mine.

Dragger multigas detector.

preference over others such as Wi-Fi for the establishing of wireless network because it provides a large range of coverage and less fluctuation in the signals.

Colour charting detectors

These types of detectors are filled with some chemicals and changes the colour according to the concentration of a particular gas present in the atmosphere. Later the colour of the tube is matched with the chart and the percentage of the harmful gases can be determined. Eg P.S detector, Hoolamite detector, Drager-multigas detector.

Automatic fire damp detector

MQ4

Automatic fire damp detector

Many companies have now started producing automatic detectors which tells the exact concentration of the gases present in the mine environment, these devices are able to detect even a very small amount of gas percentage. some of the leading companies that manufactures these kinds of devices are EMCOR, M.S.A Ltd. , Uptron etc. these gas detecting devices are also featured with adjustable probe to take the readings from the roof. Eg Automatic fire damp detector, Interference Methanometer, memacs I etc.

Gas detecting sensors

These sensors are used in the chemical plants to detect the gas leakages. These sensors have now started to find application in the underground mines for the continuous monitoring of the harmful gases. Eg MQ4, MQ7.

COMPONENTS OF THE WIRELESS NETWORK THIS MONITORING SYSTEM CONTAINS SEVERAL COMPONENTS LIKE

boards (Arduino board and Zigbee USB interfacing board), LCD (Liquid crystal display), different sensors and other small electronic components.

Arduino UNO

The Arduino board is a specially designed circuit board for programming and prototyping with Atmel microcontrollers. The microcontroller on the board is programmed using the Arduino Programming Language (based on Wiring) and the Arduino development environment (based on Processing). It is relatively cheap and plug straight to computers USB port or power it with an AC-to-DC adapter or battery to get started[5].

Zigbee USB Interfacing Board

Zigbee (Xbee) USB Interfacing Board is used to interface Xbee wireless module with computer systems. This Board is used to connect Zigbee modules to make communication between PC to PC or laptop, PC to Mechanical Assembly or robot, PC to embedded and microcontroller-based Circuits.

Table 5: Famous mine disasters due to gas leaks

S.no.	Date	Place of Accident	Cause of Accident	Fatalities
1.	Sep 6, 2006	Nagda incline of Bhatdih colliery, BCCL, India	Explosion in the mines due to the accumulation of methane	50 miners were declared dead
2.	Feb 22, 2009	Tunlan, Underground coal mine, Northern China	Poor ventilation responsible for the accumulation of the methane gas	77 miners were dead and 114 were hospitalise ed
3.	Oct 28, 2013	Underground coal mine, North Western area, Spain	Accumulation of methane gas	6 miners have been recorder dead

Arduino UNO Board

As Zigbee communicates through Serial Communication so other end of USB, which is connected to a PC, treated as COM port for Serial Communication. It is provided with indication LEDs for ease[6].

Figure 17: Zigbee USB interfacing Board

Carbon Monoxide Sensor (MQ7)

Various types of sensors are available in the market in which semiconductor sensors are considered to have fast response. MQ7 semiconductor sensor is mainly used for detecting carbon monoxide (CO).

Carbon mono-oxide sensor

MQ-7 gas sensor composed of micro Al2O3 ceramic tube and Tin Dioxide (SnO2). Electrode and heater are fixed into a crust. The heater provides required work conditions for the work of sensitive components. The conductivity of sensor is higher along with the gas concentration rising. When the sensor, heated by 5V it reaches at high temperature, it cleans the other gases adsorbed under low temperature. The MQ-7 have 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current[7].

MQ-4 Sensor and MQ-4 Module

Methane Gas Sensor (MQ4)

MQ-4 gas sensor composed of ceramic tube and Tin Dioxide. Electrode and heater are fixed into a layer. The heater provides required work conditions for the work of sensitive components.

When the target combustible gas present, the conductivity of sensor is higher along with the gas concentration rising. The MQ-4 sensor has 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current[8].

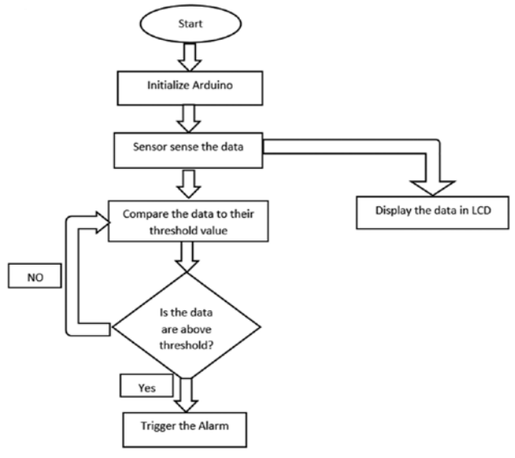
SYSTEM ARCHITECTURE

This monitoring system mainly consists of two units. First one is Sensor Unit another one is Monitoring unit.
Sensor unit contains two parts:

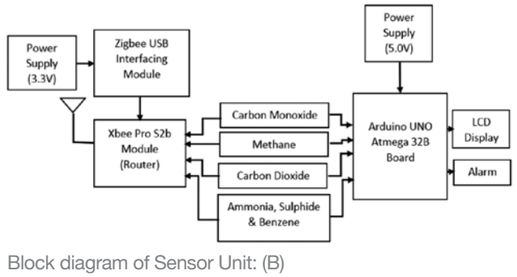
Display Unit (A)

Transmitter Unit (B)

Display unit consist of the Arduino board, sensors, and the LCD. The transmitter unit consists of a router and the sensors.



Flow chart of the monitoring System for Sensor Unit: (A)



Block diagram of Sensor Unit: (B)

INSTALLATION ZONE

The following are the main places to install the detector:

- **Goaf area:** This is one of the main places from where gas can be leaked
- **Return airway:** The importance of return airway cannot be underestimated. It can carry enough of the hazardous gases
- **Near faults, fractures or any such geological discontinuity:** These places are also prone to gas leaks
- **Where the percentage of organic matter is high:** High percentage of organic matter means more gases. So, where coal percentage is higher than the rest, we must put the sensors.
- Near the roof to detect methane layering.
- Near the working face9.

CONCLUSION

This paper deals with the hardware implemented for the real time monitoring system and how to proceed if the presence of any of the harmful gas have been detected. The details of each components used were described briefly based on its functionality and specifications. The flow chart and block diagram show the organization and working of the system. This system also stores all the data in the computer for future inspection.

ACKNOWLEDGMENT

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ABEL supplies two HMQ pumps for International Mining Industry

ABEL continues to strengthen its global presence in the mining sector. The latest additions to this market are orders for two HMQ pumps (Hydraulic Quadruplex Diaphragm Pump) received the Northern German pump manufacturer from Peru and Macedonia.

One HMQ pump will be used to transport tailings in a mine in Peru at 4600 masl, which is a big challenge that ABEL will overcome. Our customer is planning on increasing production to achieve the market requirements and they have trusted on ABEL HMQ reliability for that purpose on the tailing management facility.

Our customer in Macedonia has decided to make a big step forward on the tailings management by constructing a new Paste Plant on site that will serve to avoid the usage of the tailing dam. With this process on duty (>75% solid content), natural environment is strictly respected and safe. ABEL HMQ will serve as a key partner of the paste plant to backfill the underground stopes while the mine keeps advancing at a faster pace.

These two orders specially reinforce ABEL image on the tailing management: thickened tailings transport, backfilling, and dry stacking.

The robust design, ease of operation, high availability and low maintenance, and proven track record of more than 110 installations worldwide for various combinations of highly concentrated ash slurry (fly ash + bottom ash, salt water) make ABEL reciprocating diaphragm pumps the preferred choice for pumping abrasive slurry in various industries.

New advances in automatic shearer cutting technology for thin seams in Chinese underground coal mines

Automatic mining technology is the ideal path and the inevitable way to improve production efficiency, reduce labour intensity and ensure safety for thin coal seam. Recently, while automatic mining technology is increasingly applied in China for thin seams, the corresponding automatic cutting technol- ogy has made new advances. Among them, mnemonic cutting technology has been fruitful industrial tested with suitable conditions. Simultaneously, another one called cutting trace pre-set technology of the shearer has been put forward. Using this method, the cutting trace in the area with coal thickness changed and geological structures can be preset. What's more, self-adaptive regulation strategy of cut- ting trace based on coal-rock recognition by monitoring current of cutting motor was discussed. Then, the main problems and development trends of automatic mining in China was also proposed.

The reserves contained in thin coal seams (less than 1.3 m in thickness) are enormous in China. Among 95 national key coal enterprises, a total of more than 750 thin coal seams exist in 445 coal mines. The mineable reserves of thin seams are about 6.5 billion tons, approximately account- ing for 20% of the total recoverable coal reserves (Li *et al*., 2012; Zhao et al., 2014). The statistical results of thin coal seam reserves in selected provinces in China are shown in **Table 1** (Hai-peng, 2004; Liu and Liu, 2002; LV, 2009; Wang et al., 2012).

As the primary mineable coal resources, thick coal seams are depleted in some coal mines in recent years. In order to improve the mineable reserves and extend their service life, it is of great importance to excavate thin seams in many minefields, such as Huaibei, Huainan, Zibo, Yanzhou, Hancheng, Handan and Yulin. Currently, the intensity of excavating thin seams is increasing. However, these mines have been in a long-term difficult situation, including high labor intensity, low automation and safety level and poor economic performance. In the panel of thin seam, the height of the workspace is about 1.3 m. So the operators have to stoop down to operate the shearer or hydraulic supports, as shown in **Figure 1**.

Table 1: Statistics of thin coal seam mineable reserves in some provinces in China.

Province	Hebei	Shanxi	Inner Mongolia	Liao-ning	Jilin	Heilong-jiang	Hunan	Gui-zhou	Henan	Sichuan
Reserves (Mt)	327	1380	197	198	65	44	41	464	524	1480
Proportion (%)	16.8	17.6	15.1	12.9	18.3	1.35	28.9	37.2	12.3	51.8

Figure 1: The operator is stooping to operate the shearer in the thin panel.

Limited by these detrimental factors, the production of thin seams takes merely 10.4% of the total coal production nationwide (Yuan, 2011). It is extremely inharmonious with respect to the recoverable reserves. Therefore, development of high efficient excavating techniques for thin seams has become the focus of government and society concern.

Currently, theoretical research and engineering practice about the mining technology and equip- ment for thin seams have been carried out at home and abroad (Fang *et al*., 2008; Guo, 2013; Liu, 2011; LV, 2009; Wang, 2009, 2016; Xu *et al*., 2012; Yuan, 2011). As a result, mechanized and automatic mining is the ideal path and the inevitable way to improve production efficiency and reduce labor intensity for thin seam (MAO *et al*., 2011; Wang and Tu, 2015; Yuan, 2017). However, automatic mining can be achieved only in suitable conditions, such as coal thickness changed very little or without geological structures. The degree of automatic mining is generally low because of the complexity and diversity of deposit characteristic in China.

CURRENT SITUATION OF AUTOMATIC MINING TECHNOLOGY IN THIN SEAMS

There are two major automatic mining technologies for thin seams: one using a coal shearer and the other one a plough. Coal shearer has the advantages of high cutting efficiency, high ability of coal-rock breaking and good adaptability. It is the primary approach of mechanized excavation for thin seam in China. According to incomplete statistics, among the mechanized working faces for thin seam, those involving coal shearer takes 85%. Limited by poor ability of coal rock breaking, low stability and harsh requirements on geologic conditions, the promotion and application of plough in mechanized working face of thin seam in China is limited. Without explanation, auto- matic mining technology in the paper is the one involving a shearer.

In recent years, with more and more attention paid on automatic mining technology and equip- ments, the corresponding applications in thin seam working face have been made great progress in China, such as panel 44305 in Yujialiang Coal Mine, panel 4602 in Yangcun Coal Mine, panel 1001 in Huangling No.1 Coal Mine and panel 8812 in Tangshangou Coal Mine, etc. Among of them, fully mechanized mining equipments including shearer, hydraulic support and scraper con- veyer in panel 44305 were imported. On the contrary, the equipments in panel 4602 and panel 8812 were completely made in China. The key equipments in automatic mining have been realized localization.

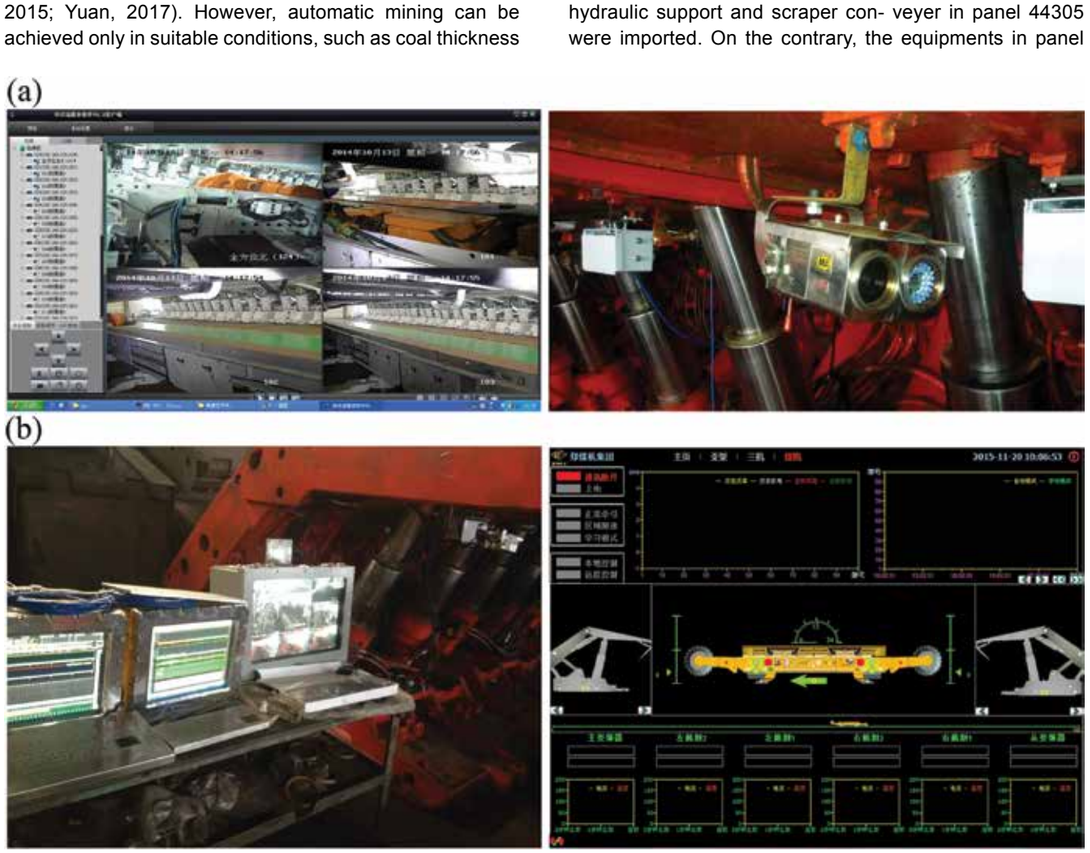

Figure 2: The key equipment in automatic cutting: (a) video surveillance system; (b) shearer remote control system.

According to these applications in China, the geological conditions in these working faces involved were well adapted for automatic mining. The typical features of automatic mining are mostly based on mnemonic cutting technology with centralized control system, video surveillance system and electro hydraulic control system (Fan *et al*., 2012b; Tian, 2011; Wang, 2016; Wang and Huang, 2014).

Automatic cutting technology is the core of the automatic mining. Based on the current devel- opment, mnemonic cutting is the main technology with the auxiliary one cutting trace pre-set tech- nology. The former is the most commonly applied and adapted to the panel with relatively simple geological conditions. The latter one is rarely used, which is suitable for the panel with relatively complex conditions, such as coal thickness changed greatly or geological structure. Aimed at auto- matic cutting, the corresponding key equipments consist of video surveillance system, shearer remote control system, as shown in **Figure 2**.

MNEMONIC CUTTING TECHNOLOGY

Mnemonic cutting can be divided into three stages. Firstly, the sampling cut along the coal seam in the working face is carried out by manual control. In the stage, the location and state information of the shearer during the sampling cut is recorded and stored by the control center. Then, during the normal cutting process, the operating parameters of the shearer are automatically controlled accord- ing to the information revealed by the sampling cut. At last, when variation arises in coal-rock inter- face, the location and state parameters of the shearer should be timely corrected by the operator according to the feedbacks from video surveillance and electrohydraulic control system. The amended and corrected cutting cycle is used as a new sampling cut, as shown in **Figure 3**.

In mnemonic cutting, the parameters involved are obtained from the sampling cut. However, these parameters should be timely and frequently updated because of the complicated and variable geological conditions. Therefore, mnemonic cutting technology has poor adaptability to geological conditions changed greatly. It is applicable to the panel with leveling roof and floor and steady dip and thickness of seam.

Longwall panel 8812 is located in Tangshangou Coal Mine in China Coal Group. As the exca- vated coal seam, the 8# seam thickness is 1.0-1.8 m with an average of 1.4 m, and the dip angle is 3°-5°. The thickness and dip are relatively steady. No geological structures were exposed during tunneling and excavation. Moreover, the roof and floor in the panel are leveling and stable. Rely on the stable geological conditions, automatic mining technology with mnemonic cutting was applied in the panel. MG2×160/710-AWD shearer was used for coal breaking. During the normal cutting process, the operating parameters of the shearer were automatically controlled according to the sampling cut **Figure 4**.

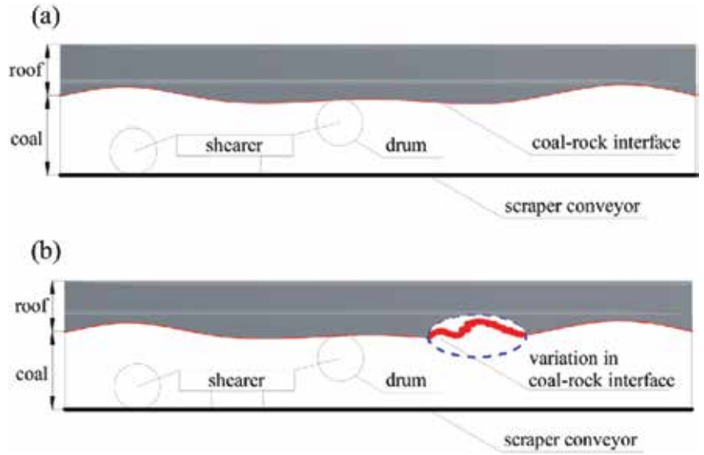

Figure 3: Schematic diagram of mnemonic cutting technology: (a) sampling cut; (b) cutting trajectory amended and corrected.

In the panel, the environment geological conditions were not immutable. According to the feed- backs of the conditions from video surveillance system and sensors, the corresponding parameters in the sampling cut should be timely amended by the shearer operator. Then, the shearer can be operated based on the parameters revised through shearer remote control system, as shown in **Figure 5**. The industrial field tests in the panel 8812 results showed that mnemonic cutting can be realized with the assistance of precise positioning, attitude determination technology and remote control. During mnemonic cutting, the shearer was operated smoothly and the faulty rate was controlled at around 3% to 5%.

CUTTING TRACE PRE-SET TECHNOLOGY

Compared with mnemonic cutting, cutting trace pre-set technology has better adaptability to geo- logical conditions, such as coal thickness changed and geological structures.

CUTTING TRACE PRE-SET TECHNOLOGY IN THE PANEL WITH COAL THICKNESS CHANGED

Based on advance exploration about the seam thickness, the distribution law of thickness is revealed in the panel. Cutting trace of the shearer in this area can be pre-set according to the law.

With respect to advance explorations about seam thickness, geophysical technology using seismic wave transmission is usually applied. Using this technology, 2# coal seam thickness distri- bution in panel 22204 in Guoerzhuang Coal Mine was obtained, as shown in **Figure 6**. The average seam thickness in the monitoring area is about 1.4 m.

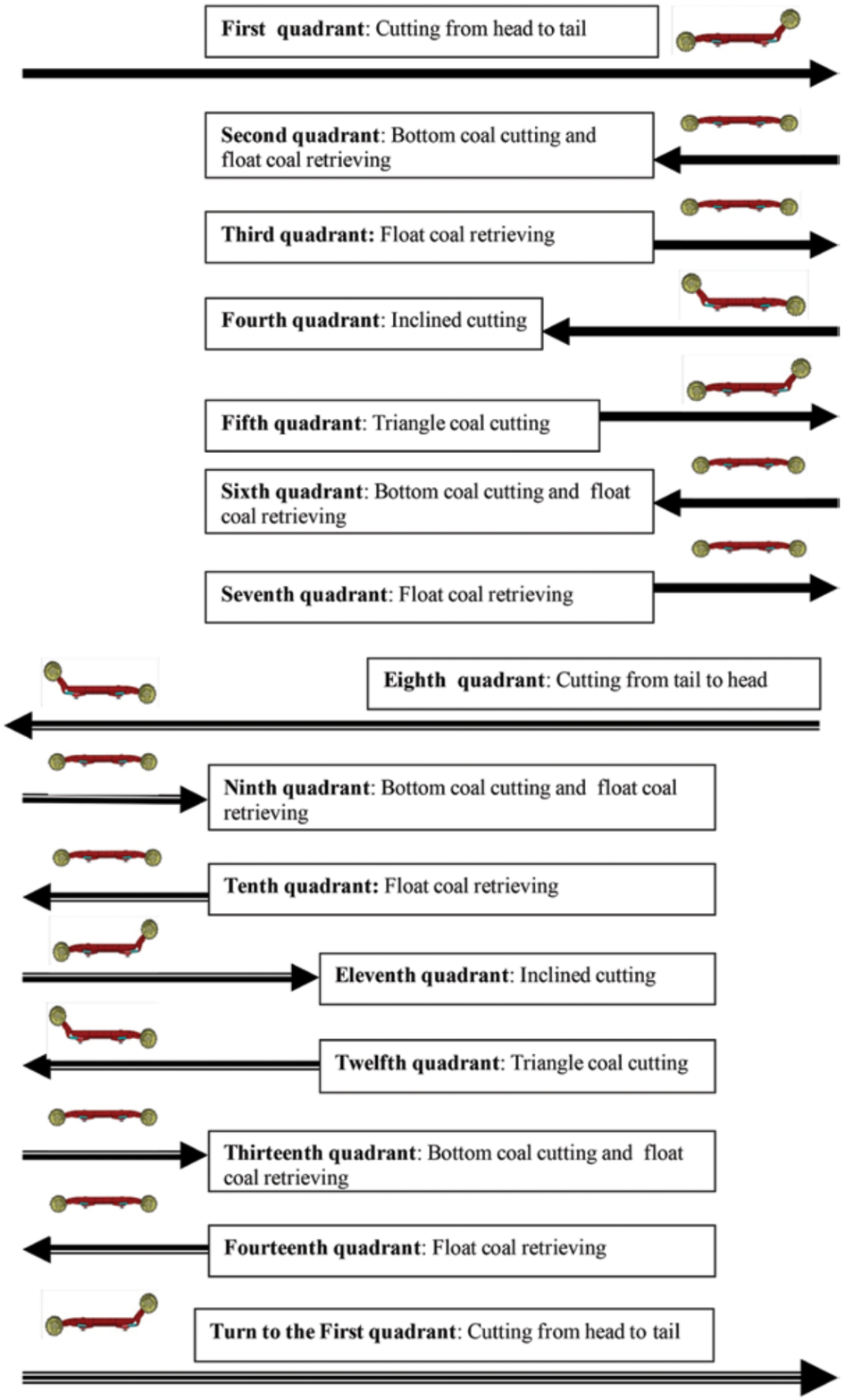

Figure 4: Flow chart of mnemonic cutting technology.

Figure 5: Shearer operation through remote control system.

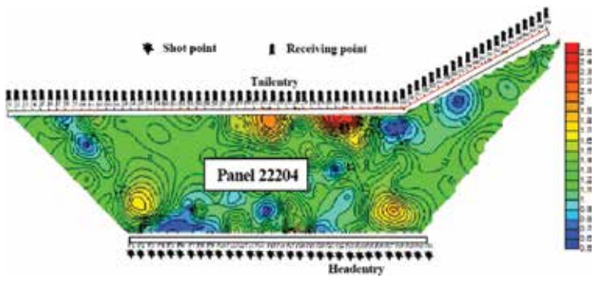

Figure 6: Coal thickness distribution in panel 22204.

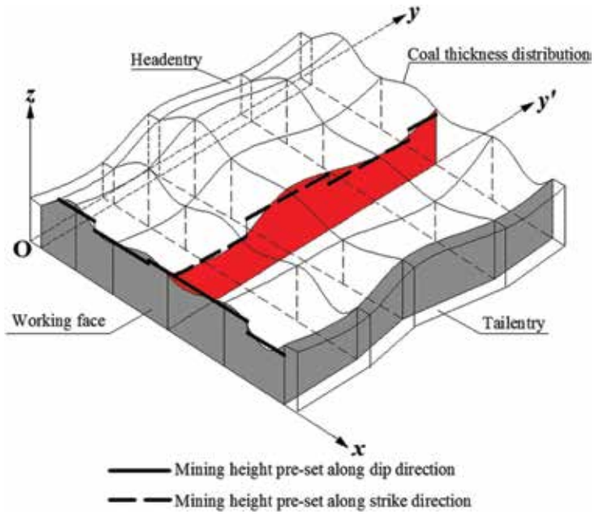

Figure 7: Cutting trace pre-set in changed area of coal thickness.

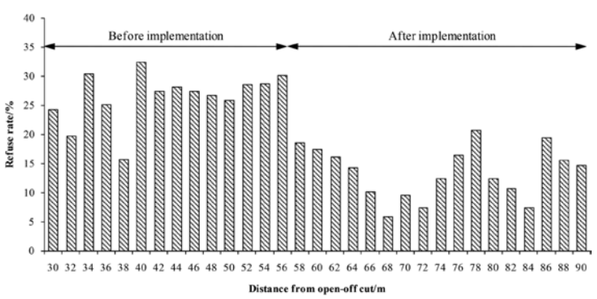

Figure 8: Refuse rate before and after "floating mining height" implementation.

According to the advance exploration results, the distribution function about the seam thickness was constructed. Then it was stored and introduced into the shearer cutting controller. Combined with the contour line of floor and roof, the graphic model about the mining height and the cutting trace in the panel was pre-built.

To achieve higher recovery, less refuse content in raw coal and better implementation effects, cutting trace pre-set technology called "floating mining height" (Wei, 2015) was put forward. In another word, mining height along dip and strike direction was pre-set according to the coal thick- ness distribution in the two directions, as illustrated in **Figure 7**.

An industrial test was carried out in the panel Wu222120 in Pingyu No.6 Coal Mine in China. The seam thickness in the panel varied from 0.8 m to 1.8 m with an average of 1.3 m. MG200/ 456-WD shearer with mining height ranged from 1.1 m to 2.4 m was applied. In order to reduce the refuse rate and increase the degree of automation, "floating mining height" technology was adopted. The statistic refuse rate before and after the implementation was obtained, as illustrated in **Figure 8**.

As shown in field industrial test, the average refuse rate reduced from 26.5% to 13.5% by "float- ing mining height" implementation. According to an uncompleted statistics, the failure rate is about decreased by 20% simultaneously. Reliability and economy of automatic mining were improved significantly by "floating mining height".

CUTTING TRACE PRE-SET TECHNOLOGY IN THE PANEL WITH GEOLOGICAL STRUCTURES

As the most common geological structures, faults and folds often exist in the working face.

Cutting trace pre-set principle while passing through fault

Using electromagnetic wave detection, occurrence parameters of a fault including drop, dip angle and range can be advanced revealed (Sun and Wang, 2015; Zhang *et al*., 2007; Zhang and Liu, 2006). Taking a normal fault as an example, a related model was constructed, as shown in **Figure 9**. As the cutting trace pre-set principle, engineering quantity of rock cutting is minimized while passing through the fault. According to the geometric relation, when the sum area of triangle ABC and EFG is minimized (Wang, 2016), the line BD and FH is the optimal cutting trace when passing through the fault. The formulas to calculate the two lines are following:

Equation 1

$$\text{Line BD}: y = \tan\gamma \cdot x + \frac{m}{2\cos\gamma}$$

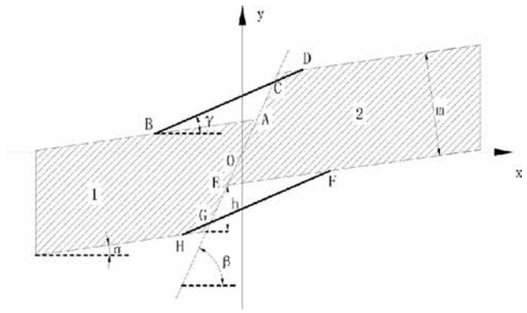

Figure 9: Cutting trace while passing through fault.
Note: 1-upper wall; 2-lower wall; α-dip angle of coal seam; *β*-dip angle of fault plane; h-drop of fault; O-origin of rectangular coordinate system; B,H-starting points of cutting trace; D, F-destination of cutting trace; A-intersection of upper surface in upper wall and fault plane; E-intersection of lower surface in lower wall and fault plane.

Equation 2

$$\text{Line FH}: y = \tan\gamma \cdot x + \frac{m}{2\cos\gamma}$$

where *γ* is the maximum elevation of the shearer when passing through fault, °. *m* is the seam thickness in the panel, m.

Cutting trace pre-set principle while passing through fold

Using in-seam seismic method, occurrence parameters of a fold including bottom radius, top radius, coal thickness, arc length, central angle, etc. can be detected. Same as the cutting trace pre-set prin- ciple while passing through the fault, engineering quantity of rock cutting is minimized while passing through the fold. Taking a circular fold as an example, a related model was constructed, as shown in **Figure 10(a)**. According to the geometric relation, the formulas to calculate the trajectory are following (Wang, 2016):

Equation 3

$$\text{Line AB}: y = a + m$$

Equation 4

$$\text{Line CD}: = a$$

where *m* is the coal seam thickness in the panel, m. a is a constant which can be calculated from the following:

Equation 5

$$\begin{cases} S_1 = S_2 \\ S_1 = \dfrac{r_1^2 - (a+m)^2}{\cot\dfrac{\theta}{2}} - \arcsin\dfrac{\sqrt{r_1^2-(a+m)^2}}{r_1} \cdot r_1^2 + (a+m)\sqrt{r_1^2-(a+m)^2} \\ S_2 = \arcsin\dfrac{\sqrt{r_2^2-a^2}}{r_2} \cdot r_2^2 - a\sqrt{r_2^2-a^2} \end{cases}$$

where S_1, S_2 is shown in **Figure 10(b)**. r_1 is the top radius of the fold, m. r_2 is the bottom radius of the fold, m. θ is the central angle of a segmentation in the fold, which can be calculated from $\theta = \alpha / n$, α is the central angle of the fold, °. n is the number of the segmentations. As a result, the cutting trace can be pre-set while passing through a circular fold in segmentation, as illustrated in **Figure 10(c)**.

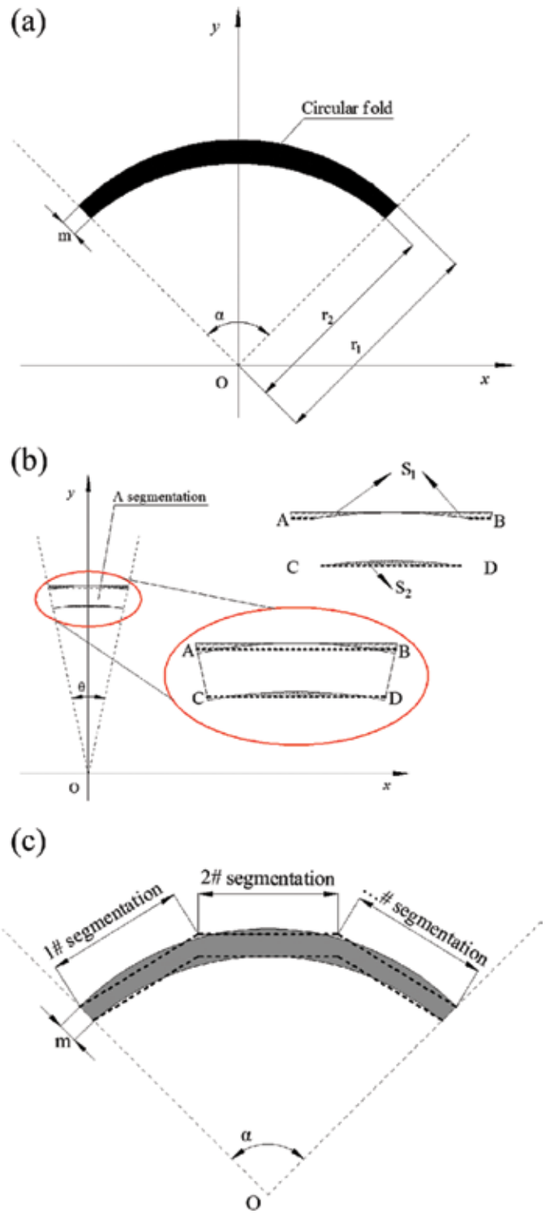

Figure 10: Cutting trace pre-set while passing through circular fold in segmentation: (a) model of a circular fold; (b) model of a segmentation in the circular fold; (c) cutting trace in segmentation.

In the process of shearer cutting, the cutting force can be measured and controlled (Haber-Haber *et al*., 2007; Reid *et al*., 2014), so as to realize the adaptive adjustment of the cutting trace pre-set. What's more, directional hydraulic fracturing and roof cutting technology are usually applied when the cutting force increases rapidly (Fan *et al*., 2012a; He *et al*., 2017).

Using the cutting trace pre-set technology above, engineering quantity of rock cutting and cutting pick consumption were reduced while passing through the fault or fold. In fact, the cutting trace should be constantly optimized according to on-site environmental characteristics. In summary, the cutting trace pre-set technology provides a good technical reference when passing through geological structure automatically.

COAL AND ROCK INTERFACE IDENTIFICATION

Coal and rock interface identification can provide powerful technological support for above self- adaptive regulation strategy. Therefore, the cutting trace pre-set technology can be realized. At present, there are many technologies applied in coal and rock interface identification, such as radio-active detection, vibration monitoring, electromagnetic measurement, infrared detection, image recognition and electrical parameter monitoring.

Taking current monitoring as an example, the current of shearer will change greatly due to dif- ferent hardness of coal and rock. Based on the principle, coal and rock interface can be identified by monitoring current of cutting motor.

In the first stage, the sampling cut is carried out in "coal-roof" by front roller, "coal-floor" by rear roller and coal by the two rollers of the shearer. Respectively, four cutting currents are monitored as I1s, I2s, I1c and I2c. During the mining process, two current sensors are installed in the two rollers respectively to monitor and feedback the cutting current, as shown in **Figure 11**.

According to the cutting current monitored I1 and I2 of the front roller and rear roller respectively, the strategy to adjust the two rollers automatically based on coal and rock identification is shown in Table 2. During the shearer selection, the safety factor of the cutting motor is larger, which leads to inaccurate identification of coal and rock interface based on current monitoring (Tian *et al*., 2016). Similarly, coal and rock interface identification can be realized by force monitoring to some extent. However, the different coal and rock properties of each working face lead to its limited application range (Huang and Liu, 2015).

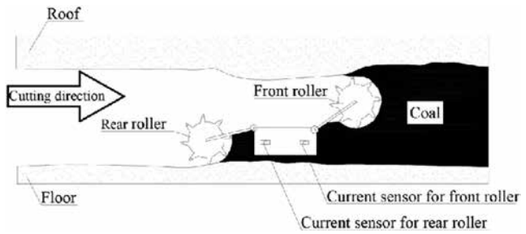

Figure 11: Cutting current monitor and feedback in the panel.

There are many problems in coal and rock interface recognition technology, such as complex working face environment, single sensor data, complex data processing etc. Coal and rock interface identification technology should be the fusion of multi-sensor data network and a variety of tech- nologies in the future. Coal and rock interface identification should be one of the priorities in the future research in automatic mining.

MAIN PROBLEMS AND PROSPECTS

Main problems

At present, automatic cutting technology for thin coal seam faces many problems in China, includ- ing the following:

1. Economic benefit is unfavorable in thin seam mining because of the relatively larger input-output ratio. Additionally, equipment for automatic cutting technology is a big investment. Promotion and application of automatic cutting in thin seam is more formidable.

2. The adaptability of the equipment and technology for automatic cutting needs to be improved. Automatic control and fault diagnosis functions for shearer must be realized accurately in com- plicated geological conditions. The sharpness of video monitoring system in the narrow working space can't be guaranteed while automatic cutting in the panel. Besides, existing coal-rock iden- tification is not yet implemented accurately.

3. The trade-off between installed power, machine height and delivery coal space is still the main problem in automatic mining working face. High-power shearer and corresponding hydraulic supports with smaller machine height need to be developed urgently.

Table 2: Self-adaptive regulation strategy to adjust the two rollers.

Roller	No.	Cutting current	Strategy
Front roller	1#	$I_1 \approx I_{1c}$, no obvious fluctuations	Upswing
	2#	$I_1 > I_{1c}$, skyrocket-increase	Ending adjusting and cutting based on the previous mining height
	3#	$I_1 > \alpha I_{1s}$, obvious fluctuations	Downswing
Rear roller	4#	$I_2 \approx I_{2c}$, no obvious fluctuations	Downswing
	5#	$I_2 > I_{2c}$, skyrocket-increase	Ending adjusting and cutting based on the previous mining height
	6#	$I_2 > \beta I_{2s}$, obvious fluctuations	Upswing

Note: α is the coefficient preset according to the hardness between coal and roof; β is the coefficient preset according to the hardness between coal and floor.

4. Most of coal mines in China suffer from a lack of experienced and knowledgeable automatic mining workers and engineers.

PROSPECTS

In China, it is a long journey to realize automatic mining in thin seams. Automatic cutting should be respected for continuous improvement. Simultaneously, further research should be undertaken.

1. For thin coal seam mining, geological conditions exploration and evaluation is an important foundation. The corresponding 3D geological model for mining should be definitely estab- lished. Coal seam thickness, seam inclination, structure, Protodyakonov coefficient, roof and floor conditions, faults and folds, gas outburst, and water inrush *et al*., should be exposed in the model.

2. The goal of automatic cutting in thin seam is a totally man-free working face. Improving adapt- ability of the auxiliary equipment and technology is the trend in automatic cutting process. To realized man-free mining, advanced technology including artificial intelligence, Big data, Internet of things, mining management information system etc. can be recommended.

CONCLUSIONS

The typical features of automatic mining in China are mostly based on mnemonic cutting technol- ogy with centralized control system, video surveillance system and electro hydraulic control system. Mnemonic cutting technology is adapted to the panel with relatively simple geological conditions.

In the panel with relatively complex conditions, another automatic cutting technology called cutting trace pre-set is put forward. Cutting trace pre-set technology is suitable for the panel with coal thickness changed greatly or geological structures. Then, the process of cutting trace pre-set with coal thickness changed and geological structures is explained.

In addition, a thought of coal-rock interface identification by monitoring current of cutting motor is proposed.

Aimed at automatic cutting in China, the main development trends include developing high- power shearer and corresponding hydraulic supports with smaller machine height, establishing 3D geological model and improving adaptability of the equipment and technology.

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