The Epiroc Häggloader is a continuous loading system for underground operations

Electric dreams

Ailbhe Goodbody look at trends in underground load and haul, such as the increased demand for electric vehicles

In the underground load and haul space, as in many other areas of the mining industry, mines are looking for products that transport more tonnes per energy unit, provide a safe workplace for mine personnel and benefit the overall productivity of the mine.

However, there is growing demand for loader and truck automation and connectivity. Customers are asking original equipment manufacturers (OEMs) for increased customer safety, productivity and lower operating costs through the use of automation.

"Customers are expressing strong interest in automation technologies that can help their mines enhance safety and lower costs. That's why our new R1700 load-haul-dump (LHD) is automation-ready from the factory," says Nathan Wescombe, underground hard rock vehicle commercial manager at Caterpillar. "We are also seeing more interest in high-level diesel emissions controls. Caterpillar offers multiple levels of emissions control, including a system that meets Stage V standards."

Related trends are data collection and analysis of the load and haul equipment in order to monitor the status and productivity of the equipment, as well as for predictive maintenance planning. Customers are looking to monitor the productivity, availability and effective utilisation of the equipment. Dr Jan Olaf Petzold, managing director at GHH Fahrzeuge, notes: "Customers ask for automation-ready equipment, on-board data collection systems and the software for analysis."

Marcus Eklind, global product line manager, underground material handling at Epiroc, says: "Automation is not just about the autonomous operation itself but also about optimising processes to reach higher utilisation grades of equipment, and control which can be derived from efficient and structured monitoring.

"So it's not just about the equipment collecting data, but about sending data in real time to be able to act and plan based on the data sent. Mines are seeking technology integration, with the flexibility to scale features from basic automation to a fully autonomous operation, resulting in high safety as well as efficiency gains."

Aramine has also seen an increasing demand for narrow-vein mining equipment. Marc Melkonian, Aramine co-president, suggests: "This increasing demand for narrow-vein mining equipment can be explained by the flexibility of development and the lower capital investment required. This allows faster return on investment, especially in these days of big fluctuations in raw material costs."

Petzold agrees: "Due to deeper mines, and the complexity of the geology in such deep mines, we see a higher demand for smaller equipment than in the past."

Mining companies, to a larger extent than in the past, also ask for complete packages including financing solutions or rental and ►

"There is growing demand for loader and truck automation and connectivity"

aftermarket services. Eklind says: "This means that we see strong partnerships with focus on automation."

Melkonian agrees: "Customers are expecting rental solutions and full maintenance contracts. Aramine offers these possibilities."

DEMAND FOR ELECTRIC VEHICLES

As orebodies close to the surface become depleted, mines are going deeper and getting hotter. As mines get deeper, the cost to have sufficient ventilation to run diesel-powered equipment is significant.

Mining companies have a strong focus on regaining their productivity to improve their position on the cost curve relative to competitors. This increase in productivity must also be safe, cost-effective and sustainable – this is where electrification enters the room.

Eklind explains: "As excavations go deeper, in turn the cost of installing and operating fans, heating and cooling grows significantly, which results in additional strain on the existing ventilation and cooling systems and requires expensive upgrades."

This is one of the reasons that there has been a noticeable upswing in demand for electric vehicles in underground mines in certain markets such as North America and Europe. An electric power source for load-and-haul vehicles enables a better usage of energy to move tonnes of ore, which can significantly reduce the need and cost for ventilation. Kevin Fitzsimmons, managing director, sales and marketing at RDH Scharf, says: "Clients are definitely interested in understanding battery technology in loading and hauling. Each year, since 2010, from our first prototype, it has gained more and more traction."

The combustion of diesel fuel and oxygen produces a lot of heat which must be removed from the mine using ventilation and refrigeration systems. Wayne Scrivens, vice president product line load and haul at Sandvik Mining and Rock Technology, states: "By removing the diesel engine, the source of heat is significantly reduced, potentially enabling customers to reduce ventilation requirements for these deep mines."

The cost savings from reduced ventilation requirements is a huge benefit, as well as the elimination of diesel particulate and heat caused by running diesel engines underground. Jens Steinberg, commercial manager at SMT Scharf, says: "Many engineering firms doing pre-feasibility and feasibility studies [for underground mines] are planning with battery technology and the ventilation saving aspects and designing their ventilation infrastructure for a reduced requirement. These savings in ventilation far outweigh the battery technology upcharge."

The Cat R1700 underground loader working

There are also environment, health and safety (EHS) benefits from removing diesel exhaust from underground. Petzold notes: "We believe it is to reduce the air pollution underground in order to protect the health of humans working underground."

Erik Svedlund, marketing manager, product electrification at Epiroc, agrees: "The increased interest in electrification is coming from the need to improve [the] underground working environment. Electrification of underground machines has major benefits in the areas of safety, health, productivity and energy use."

In addition, equipment providers are currently stretching the diesel technology to the limit with EU Stage V and US Tier 4 Final emission legislation, which increases the complexity of equipment. Svedlund says: "The increased complexity and requirement for clean low-sulphur fuel has definitely made our customers look at alternatives such as electrically powered vehicles."

SMT Scharf has also noticed many new clients looking, trialling and purchasing battery equipment as a result. Fitzsimmons explains: "New European regulations are starting to be enforced to push mining companies down to a very significant reduction in emissions, which diesel currently is not able to meet."

Melkonian agrees: "We have noticed an increased interest for electric vehicles, especially for battery-powered vehicles. Customer demands follow a number of new political trends, including ecological awareness and wellbeing at work. Electric vehicles are the perfect answer to both those tendencies.

"In the last 3-4 years, we have observed an increased tendency for electric and battery-powered equipment. Indeed, customers seem to be more concerned by environmental matters these days."

The increased interest in electrification also comes from the fact that the technology is rapidly developing, and we are seeing more and more electric cars and other vehicles in our everyday life. Svedlund says: "With over four years of experience running battery-powered loaders and trucks in real operations, Epiroc clearly sees the benefits in terms of higher productivity, reduced cost and improved health and safety for underground operators."

EQUIPMENT PROVIDERS

There are several companies that supply equipment for underground load and haul – *Mining Magazine* speaks to some of the main equipment providers for underground mines to find out what is available.

Aramine

Aramine specialises in narrow-vein mining equipment from 5-15m^2. It has a full range of different miniLoaders (0.88m, 1m and 1.2m wide) integrating the latest technologies such as batteries and radio remote control to meet every narrow-vein mining client's needs.

In some cases, Aramine's machines can even be operated in low-profile mines thanks to an optional low-profile canopy. Its range of mini-loaders has expanded with a mini mining truck, the mini-Dumper T500, that was designed and manufactured in France. It also has two 15t trucks, the T1601C and the T1601M, that are available in mechanical and computerised versions and are ideal for sections from 12-18m^2. A 17.5t truck completes this range.

Aramine launched its first electric miniLoader before the increasing demand from the mining industry and introduced its first battery-powered miniLoader to the market two years ago.

"We have a productive R&D team, working every day to enhance our electric and battery-powered solutions," comments Melkonian.

In addition to manufacturing, Aramine has four different divisions. Its Aramine equipment division manufactures its narrow-vein mining machines, as well as providing a remanufactured machine programme and service and maintenance. The Aramine distribution division is an official distributor of Epiroc, Normet and BTI to offer a wide machine choice in targeted geographical areas, while its Aramine OES spare parts division provides genuine spare parts, components and accessories from different brands. Finally, the Aramine supply chain centre supplies and stocks solutions in support of the other Aramine divisions.

"There are more than 200 Aramine narrow-vein machines operating around the world for large mining companies such as Hoschild or Buenaventura in Peru, but also in Bolivia, Morocco, Mexico, Bulgaria, Serbia, the Philippines, Brazil, Kazakhstan and various Russian-speaking countries," says Melkonian. "There are more than 300 underground mining sites in 83 countries, among the world leaders in the extraction of gold, diamonds, uranium, silver, nickel and copper who trust us."

Aramine's 15t T1601C and T1601M trucks are ideal for sections from 12-18m^2

Caterpillar

Caterpillar offers a broad line of underground hard-rock mining vehicles, including six different sizes of underground loaders and four different capacities of underground trucks to accommodate a wide range of mine openings and production requirements. All of the vehicles use Cat engines and drivetrains for efficient, reliable operation and extended durability.

The Cat LHD line ranges from 6.8-20t payload. In the middle of the range is the 15t-payload R1700, which was recently commercially launched after proving its capabilities in extensive field trials.

A completely new Caterpillar design, the R1700 loader, brings new levels of productivity, operator comfort and serviceability to underground miners. Compared to the previous model, the new R1700 carries 20% more material with each pass. Increased digging forces add further to its production capabilities as does superior machine balance.

The new traction control system, which uses the new electrohydraulic braking system, limits tyre slip going into the pile, resulting in longer tyre life and reduced tyre costs. In addition, Auto Dig – fully automated bucket loading – helps new operators be productive on the first day and reduces fatigue for experienced operators. The R1700 also features operator presence and door latch monitoring for enhanced safety.

Three different engine emissions configurations, including Stage V, are available to tailor the machine to the mine's ventilation needs. The R1700 is also equipped with multiple subsystems for fast technology implementation. Remote machine health monitoring, payload monitoring as well as a full slate of remote control, semi-autonomous and fully autonomous operating technologies are available via MineStar Command for underground.

For the entire LHD line, Caterpillar now offers Bolt-On Half-Arrow ground engaging tools (GET) for bucket edges. The system is designed for high-abrasion applications where weld-on GET experience high wear rates. With a reliable retention system, the bolt-on GET offer more wear material than standard weld-on GET, and the bolt-on design enables fast and easy removal and replacement. Despite additional wear material, the low-profile front edge eases pile penetration and promotes fast bucket loading.

The Cat line of underground articulated trucks is well matched to Cat loaders, with four truck models that offer payload capacities ranging from 22-60t. The newest addition to

"Electrification of underground machines has major benefits in the areas of safety, health, productivity and energy use"

The Cat AD22 underground truck in a mine

the Cat underground truck line, the AD22, is Caterpillar's smallest but is designed to deliver the performance and durability of its larger counterparts. Its 22t payload is one of the largest in the size class.

The AD22 has a small operating envelope and agile manoeuvrability, including 45° articulation and decreased outside turning radius to enhance productivity when working in limited spaces. An oscillating hitch helps absorb haul road irregularities and enables the operator to maintain greater speed and control.

Epiroc's Minetruck MT2010 is a 20t underground truck for small- to medium-scale underground operations and development work

Like its larger counterparts, the AD22 uses Cat components such as the C11 diesel engine. Coupled to the C11 is a Cat heavy-duty torque converter with an automatic lock-up clutch and Cat planetary powershift transmission. These components are responsible for the nimble performance, speed on grade and all-wheel drive capabilities of the truck.

Four different dump body sizes are available to optimise the truck for every application and to help mines achieve the target payload based on material density. An ejector body is also offered. The AD22 offers a three-pass match to the Cat R1300G underground loader or a two-pass match to the R1600H.

Epiroc

Since 2016, Epiroc has offered 100% zero emission machines – starting with the Scooptram ST7 battery loader. Svedlund notes: "Since that launch, we have added the Minetruck MT2010 battery and the Boomer M2 battery. This is our start; we are gearing up for an all-electric future and more models will come in a very near future."

Epiroc provides a comprehensive line of equipment for underground load and haul for narrow-vein and mass mining applications, with its Scooptram loaders ranging from 3.6-18t tramming capacity (both diesel and electric), and its Minetruck trucks ranging from 22-65t payload capacity.

Eklind says: "In addition, Epiroc is the only OEM that can also provide a continuous loader; the Häggloader has a capacity from 3.5m^3/min to 5m^3/min."

Epiroc's mine truck line has application-specific options available, including ejector bodies for backfill applications, and selected underground loaders feature ejector buckets for low drift heights where a traditional dump application is not possible.

"At Epiroc we are dedicated to introducing innovative, productive and technology-leading products that bring value to our customers' business," comments Eklind. "Safety is always our number one priority, which can be seen in our products and the many smart features they offer to assist the operator to safely achieve maximum productivity. Minimal operator fatigue is ensured by the ergonomically designed and spacious operator compartments of our rigs. The best-in-class power-to-weight ratio ensures good speed on grade for high productivity. Payload management systems for the loaders and trucks allow customers to monitor production material being hauled and identify areas for improvement."

Epiroc sells load and haul equipment to all continents, and its products are in mines worldwide.

GHH Fahrzeuge's LF-14 is a 14t LHD

GHH Fahrzeuge

GHH provides LHDs with a capacity from 3-21t. This offering includes super low-profile LHDs with a capacity of 3-14t, such as its new XLP-8 that has a capacity of 8t and an overall height below 1.6m. It also provides electric-powered LHDs with a capacity up to 19t.

The company's underground trucks for mining have a capacity of 15-42t, including trucks with bidirectional operator seats.

Some of GHH's customers for its underground load-and-haul products include a K+S Group potassium mine in Germany, a Hindustan Zinc mine in India, an Alrosa diamond mine in Russia, Anglo American platinum mines in South Africa and Zimbabwe, a Mimosa Mining platinum mine in Zimbabwe and a Glencore chrome mine in South Africa.

"Mining customers seem to be more concerned by environmental matters these days"

Sandvik

Sandvik has an extensive underground loader and dump truck portfolio, including loaders with payload capacities from 3-25t and trucks with payload capacities from 15-63t. "The loader and truck product range is designed to build matching pairs, to optimise the truck loading cycle," says Scrivens. "For example, a 51t Sandvik TH551i truck can be fully loaded with three-pass loading using a 17t loader, the new Sandvik LH517i."

Sandvik's loader offering includes advanced loaders; these feature modern technology such as the Sandvik Intelligent Control System which is the software backbone for all Sandvik intelligent loaders and trucks, called the i series. This control system enables the building of multiple smart solutions such as automation readiness for Sandvik AutoMine, My Sandvik Knowledge box for data storage and transfer to the My Sandvik digital services, and the Integrated Weighing System for production monitoring.

Scrivens explains: "Additionally, the advanced loaders are designed according to the highest safety standards and considering the latest emissions regulations for off-road diesel engines."

The company's low-profile loaders are designed specifically to operate in limited heights, for example in low-profile room-and-pillar mining applications. The low-profile loaders offer payload capacities from 1.7-9.6t and canopy heights as low as 1.6m. The low-profile loaders are equipped with powerful diesel engines and high breakout forces and enable fast bucket filling.

It also offers electric loaders, which offer a possibility to utilise electric motors instead of diesel engines. In addition to zero diesel emissions, the noise and vibration levels of electric loaders are lower than in the diesel equipment.

Finally, its robust loaders with a strong and simple design are engineered to be easy to use and easy to maintain, with high uptime. "Even though digitalisation and connectivity are some of the current industry trends, reliable and hard-working equipment is needed in many applications," says Scrivens. "This kind of robust equipment is specifically appreciated in challenging environments and conditions."

Sandvik has around 20 years of experience and more than two million operating hours of self-driving in underground mines; at the same time, there have been zero accidents involving people and this self-driving equipment. The new i-series loaders and trucks that Sandvik has released are specifically designed for use with AutoMine and OptiMine.

The Sandvik truck offering consists of rugged, compact and powerful mining trucks which offer payload capacities from 15-63t. "Sandvik underground trucks are designed to transport rock material safely, efficiently and reliably in extreme conditions," comments Scrivens.

The truck portfolio consists of robust models, low-profile models and the intelligent i-series. As with Sandvik's loaders, it includes features such as readiness for Sandvik AutoMine, My Sandvik Knowledge box for data storage and transfer to the My Sandvik digital services, as well as the

Integrated Weighing System for production monitoring.

As mining customers are looking to monitor the productivity, availability and effective utilisation of the equipment, the Sandvik i-series loaders and trucks enables them to get productivity information, the payload of the bucket and box, as well as the daily number of buckets of boxes produced. Customers can track the location of the loader and truck underground and send instructions to operators on where to go.

"Combined with the whole ore-extraction process from the loading to the mill, each part of the system can then be optimised to improve overall efficiency of the mine," says Scrivens. "The health-monitoring data can be used to plan maintenance schedules and action. It can also be used to predict unwanted downtime events before they happen using OptiMine Analytics. This increases equipment availability, productivity and lowers operating costs."

Sandvik has had electric equipment, connected with a trailing cable to the mine network, in standard offering for more than 30 years. Today, Sandvik is investing in research and development in next-generation power sources and drivelines, including a new Hybrid and Battery Electrification Innovation and Development Center for loaders and trucks in Turku, Finland. Scrivens states: "This is a development facility that will create battery products and electric solutions for the global mining and construction markets and contribute in developing technology talents."

Sandvik recently delivered its newest intelligent loader, the Sandvik LH517i, to Barminco in Australia. Scrivens says: "The Sandvik LH517i is designed to meet customer expectations being safer, more reliable and efficient, supplemented with in-built intelligence enabling lower operating cost and improved connectivity."

The starting point of this new loader design was to respond to customer suggestions that were collected in forums that took place in Australia in 2015. Sandvik listened to the suggested improvements and added them to the equipment design.

"The year 2018 was significant for product area load and haul as in May 2018, the 10,000th unit was delivered from the Turku site to a customer in Mexico," comments Scrivens. "This emphasises Sandvik's extensive experience in designing and manufacturing underground load-and-haul equipment with high integrity, as well as continuous commitment to deliver high-quality units according to customer expectations."

SMT Scharf

SMT Scharf can provide a complete mobile equipment fleet to any underground mine in both battery and diesel configurations. These include one-, two- and three-boom production equipment jumbos, LHDs from 3t to 17t, and haul trucks from 4t to 50t, utility vehicles such as scissor lifts, boom trucks, service lube trucks, cassette trucks and ANFO loaders, as well as ground support bolters and shotcrete sprayers and mixers.

The Sandvik LH517i is an intelligent and efficient 17t underground loader

"We are also one of the only manufacturers that still will engineer custom solutions for a client," says Steinberg. "We tailor our machines to their requirements."

SMT Scharf aims to 'simplify heavy equipment', meaning that it makes it easy for the operators to use and easy for the technicians to maintain and troubleshoot.

The company also traditionally provides rail-bound transportation solutions such as mono-rail trains and duo-rail trains. These are used in coal mines around the globe, as well as in gold and platinum mines in South Africa, for the transport of supplies including longwall roof support shields up to 48t in weight or personnel.

Fitzsimmons explains: "We provided the first ever battery machines (lithium-based technology) to a mine in northern Ontario [Canada] that have logged over 12,000 hard working hours per machine over the past seven years and are still running in a narrow-vein production environment. Many other customers are looking at this example and are analysing the benefits for their own mines."

SMT Scharf's Haulmaster 800-20EB is a powerful, battery-powered 18-20t haul truck for mining and tunnelling applications