THOMPSON, B. Safety trends in mining. *The 6th International Platinum Conference, 'Platinum–Metal for the Future',* The Southern African Institute of Mining and Metallurgy, 2014.

Safety trends in mining

B. THOMPSON
Atlas Copco Rock Drills AB, Sweden

Safety is one of the mining industry's major concerns, especially when it comes to underground mines. The reason is obvious; accidents and injuries have disastrous consequences, both for mining personnel and productivity. Although mining has become less hazardous over the years, there are still opportunities for increasing the safety of the underground working environment.

Mines are going deeper to extract minerals, and some of the jobs are very labour-intensive. Both of these factors increase the safety hazards. The hazards faced by workers range from cave-ins to explosions, dust and heat exposure, and mobile equipment. Protecting the health and safety of our workers is priority number one, and everyone has the right to work in a healthy, safe environment.

Mobile equipment has been used for many years in underground mining. These machines are operated in dark, low, narrow tunnels which cause visibility restrictions for the operators and other workers in the area. The machines produce heat and emissions which need to be ventilated from the mine for safety.

The mining industry has been actively pushing for the development of new and better safety features and functions to prevent accidents on or around the machines. This push has brought smarter, safer machines to the market place. Some of these features are video remote, automation, and personal detection and guidance systems, to mention a few.

This paper will explore the safety features and functions brought about through the use of machine intelligence systems – how the smart machines and options of today can offer greater safety to the operator and others in the working place. Specifically, how have mining equipment manufacturers worked with end-users to develop equipment with safe solutions for their demanding requirements without effecting reliability.

We will also briefly discuss areas that require further collaboration and work in order to improve safety in the future.

Introduction

Although modern mining is a good deal less hazardous than in the past, there is still much that needs to be done in order to create a safe environment underground.

Safety is one of the mining industry's prime concerns, especially when it comes to underground operations. The reason is obvious; accidents and injuries can have disastrous consequences, both for mine personnel and for productivity.

There is no denying that accidents still occur frequently in mines around the world, and some involve fatalities, but statistics indicate that these are generally less frequent and less severe than in the past. This is due in large part to the efforts made in recent years by the world's leading mining companies and equipment suppliers, who have consistently come up with innovative solutions to a range of hazardous mining operations. Publicly available statistics from the USA (MSHA – Mine Safety and Health Administration) and Sweden (SveMin – Swedish Association of Mines, Mineral and Metal Producers) clearly demonstrate the positive trends over the past decades (Figures 1–4).

The driving force behind this trend is a common desire to eliminate risks and protect miners' lives, but also a recognition of the fact that safety goes hand in hand with the aim of achieving high and sustainable productivity.

Today's miners are better equipped for the job than ever, with modern headgear, protective glasses, ear protection, proper coveralls, and a range of personal safety devices. The equipment that is available to them is full of automatic features that help to reduce or eliminate heavy labour and reduce the risk of injury. Over the years we have moved away from open operators' compartments to enclosed cabins with air conditioning and fresh air filtration for improving the working environment.

The cabins are designed to meet the FOPS / ROPS (falling object and rollover protective structure) standards

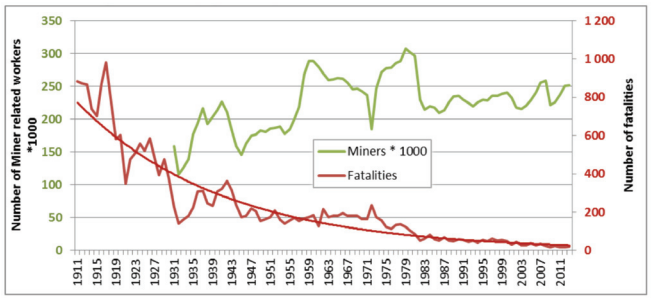

Figure 1. Mine-related workers and fatalities in the USA, 1911–2013 (including underground, surface, sand and gravel, mill – excluding coal) (Mine Safety and Health Administration, 2014)

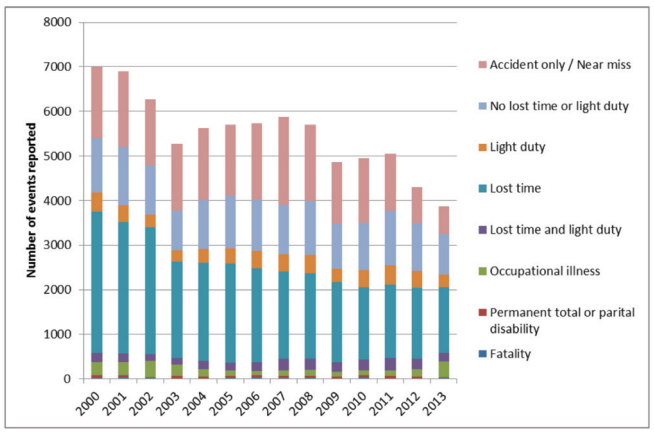

Figure 2. Severity of underground accidents reported in USA 2000–2013. Metals, non-metals, and coal included (Mine Safety and Health Administration, 2014)

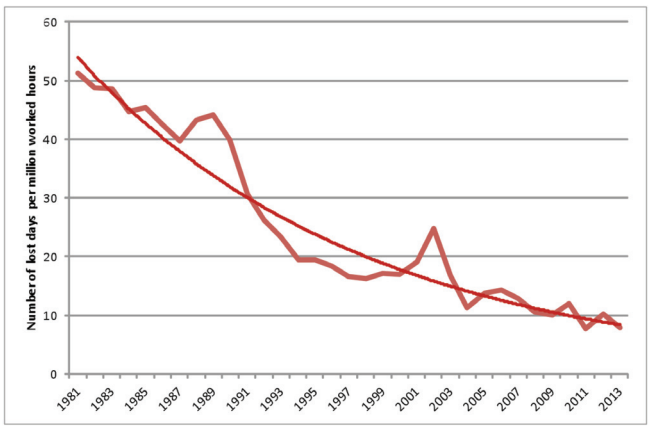

Figure 3. Occupational accidents, lost days frequency in Swedish mining and mineral industry (surface and underground) 1981–2013 (SweMin, 2013)

to provide the best protection possible for the operators in case of rockfall or roll-over. The layout and constructed spaces of the mines are also planned so that maintenance and handling of machines can be done safely.

Global supplier Atlas Copco is one of the pioneers of safety-focused mining equipment and is constantly launching new innovations. Well-protected, ergonomically designed operator cabins that give all-round visibility (Figure 5); rod handling systems that eliminate heavy lifting (Figure 6); remote control systems; fully automatic drill rigs; autonomous loaders, trucks and mechanized scaling rigs; speed limit braking and machine protection are just a few of the innovations that have been universally introduced. At the same time, significant progress has been made in many other areas aimed at improving health and safety underground, such as improved mine ventilation systems, lower emission engines, special solutions to sudden water inrushes, gas and motion detection devices, and traffic management systems designed to avoid vehicle collisions.

It is also evident that more and more mines are recognizing the crucial advantages of installing a seismic monitoring system to help forecast, notify, and identify seismic events. In fact, as operations go deeper, it is likely that this will become standard procedure and seismic

Figure 4. Severity of accidents in Swedish mining and mineral industry 2004–2013 (SweMin, 2013)

Figure 5. Seven-ton capacity low-profile loader with enclosed cabin and air conditioning

Figure 6. Automated rod handling systems such as this keep the operator out of harm's way

systems may well be viewed in the years to come as a necessary requirement, much like helmets and other protective gear.

Nevertheless, most mining companies, contractors, and suppliers would agree that there are still many aspects that can be improved and that safety is, and should remain, a never-ending quest for excellence.

Technology for safety

Over the next few years, it is reasonable to assume that the trend towards greater mechanization and automation will increase substantially – and for good reason. Such systems allow miners to maintain a safe distance from the working area, out of harm's way, while autonomous operations enable them to be removed from the most dangerous areas of the mine altogether.

A good example of automated systems eliminating risk of injury is the rod handling system used for drilling injection

Table I
Capacity of a 2-boom drill rig for drilling 24 m injection holes (Nord and Östberg, 2011)

Handling of drill steel	Sustainable drilling capacity	Improvement
Manually from service platform	70 m/h	
Mechanized rod handling	70 m/h	Improved safety, reduction of labour
Automated rod handling	100 m/h	Increased capacity

holes (Figure 6). In the past, extension drilling was performed with one operator at the drilling controls and an assistant, typically on a service platform, manually adding and removing extension drill steels. Tunnelling associations identified that the manual handling of the drill steel entailed very adverse working conditions with high risk of injury and sustained intensively physical labour (Swedish Work Environment Authority. 2010). This led to the development of a mechanized rod handling system that allowed 24 m holes to be drilled without anyone having to be outside of the drill rig's cabin. This system was later further developed to add automation to mechanization, leading to an increase in performance. The end result was the elimination of a function that involved a high risk of injuries, and at the same time increasing productivity by 40% (Table I).

Rock reinforcement in low-seam mining is another area where technology has led to safer and faster operations. Roofbolting, which was traditionally carried out manually with a hand-held rock drill, has gradually been converted to mechanized drilling and bolting, both in low-seam and extra-low-seam mining. Early mechanized versions removed the operators from unsupported ground for most of the bolting cycle, but extension drill steel and bolts still had to be handled manually in a zone with high risk of falls of ground and other injuries. Later versions of the mechanized bolting drill rig have removed the operators from unsupported ground for the complete bolting cycle by mechanizing drill steel and bolt handling (Figures 7 and 8).

Today, longhole production drilling using automated drill rigs and remote control is relatively common in underground mining. More and more mines are beginning trials with driverless, autonomous/semi-autonomous LHDs and trucks that are controlled from the safety of a control room on the surface or from a distance (long or short) in the mine.

With the rig control system we are able to provide protective safety systems built into the machines to protect operators and machines. These features include neutral brake application, door interlock, speed limiter, machine protection, and many more.

Coupled with this there has also been an upsurge of new technology in the field of personal safety equipment. Among the more interesting of these is 'the intelligent helmet' that provides a complete safety system. It can automatically sense dangers such as gas, impact, motion, and transmit warnings, coordinates, and other information to the mine office.

The human factor

At the same time, it must be emphasized that the overwhelming number of day-to-day accidents and injuries that occur in underground mines are attributed to the human factor. A disregard for safety regulations, slight errors made through the lack of training or correct information, or simply a lack of communication are all cited as root causes.

But even here, things are improving, not only because of higher penalties that can be imposed in some regions for accidents that lead to fatalities, but also because today's training courses are heavily focused on safety-first. Many of today's mining companies have adopted a zero tolerance policy in order to meet the strict safety requirements of the future. In reality, the name of the game is continuous improvement of safety procedures and the working environment. Increased automation is also playing an important role as human exposure to the most dangerous aspects of mining is being minimized. Moreover, automation means that the most monotonous tasks, which can also pose a risk, will not require human labour. This makes the industry not only safer, but more attractive in the eyes of a younger generation of miners.

Human impact on performance

These days, equipment operators are not only expected to operate their machines professionally and safely; they are

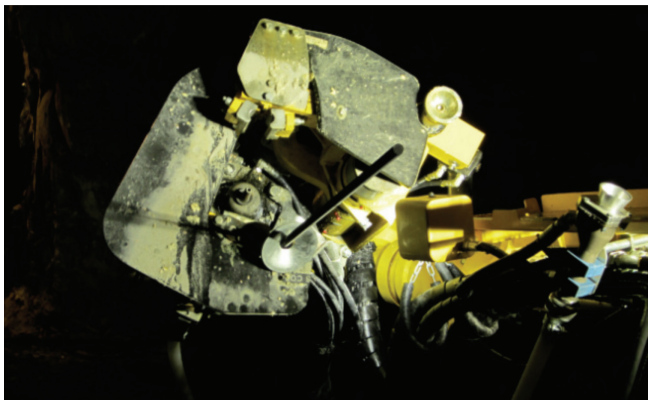

Figure 7. Bolting unit in the safe bolt loading position for low-seam rock reinforcement

Figure 8. Extra-low-profile mechanized bolter in operation

also required to have a broader understanding of their professional roles and the personal contributions they make to the success of the company they work for.

The reason for this is twofold: the increasing need for the lowest possible cost per ton and the fast pace of technological development.

Against this background, no mining company or mining contractor is prepared to put an expensive piece of equipment – a computerized drill rig for example – into the hands of an operator who is not fully trained and qualified.

Skills shortage

In the past, skilled labour was abundant. New recruits were relatively easy to find and were traditionally trained by the most experienced operators on the mining crew. Today, there is a worldwide shortage of skilled labour. New recruits are extremely hard to find and few mines or mining contractors are able to release experienced personnel from production duties in order to train new operators.

The scale of the dilemma differs from country to country, but the common goal is to find a solution that produces new, well-trained mining personnel without burdening ongoing operations.

The skills required from the operators have also changed as the mining methods and degree of mechanization evolved. In conventional mining operations, most machinery is kept to a relatively simple level with few controls, making it easy for an operator to master. With mechanization of the mines, operators are handling much more complex and powerful equipment, requiring more advanced skills. The same applies for maintenance crews, who need deeper knowledge and understanding to keep complex machinery operational.

Not only do equipment operators have to handle more complex machines, but they often have to handle more than one task or movement at one time to operate the equipment efficiently. Another dimension that has increased the skills required from operators in modern mining is the transition from rail-bound equipment to trackless mining. Rail-bound equipment had only a limited degree of freedom when travelling in the mine. However, rubber-tyred equipment needs a high level of mobility to fulfil its role in the modern mine layout.

In this context, the use of simulators for training purposes instead of real equipment and, to a great extent, outsourcing the training responsibility to external specialists, is emerging as a popular approach.

The power of simulators

The advantages of this approach are considerable. Firstly, simulator training enables operators to be trained without disrupting production or having to take experienced operators off the job. Secondly, operators can be trained on the surface where they can learn and practice in a safe environment. And thirdly, it eliminates putting trainees in charge of an expensive piece of high-technology equipment until they are fully qualified to take on such an important responsibility.

This policy reduces the risk of machines being damaged due to incorrect use and, more importantly, it reduces the enormous costs associated with disruptions to operations, time-out for unscheduled maintenance and repairs and, last but not least, accidents resulting in injuries to personnel.

Neither the mining companies nor the individual trainees need to worry about the hazards of handling machines in real mining environments, and the actual cost of training can be minimized as the time it takes to get trainees up to speed and into production is substantially reduced, which is a major advantage in the effort to meet the demand for maximum efficiency.

In recognition of the need to address the issue of personnel training, a number of leading equipment suppliers have been proactively developing their own training programmes to offer to their customers. A typical case in point is Atlas Copco's Master Driller programme, which is specially designed to match all of the mining equipment in the company's range.

Master Driller provides trainee drillers with three levels of proficiency – Bronze, Silver, and Gold – and consists of step-by-step courses that teach operators all of the knowledge and skills they need in order to take full responsibility for their Atlas Copco equipment.

The programme has been successfully implemented by several major mining companies, among them Sweden's state-owned LKAB iron ore operations and Boliden's Garpenberg Mine, Sweden's oldest base metals mine dating back to the 13th century and now a highly automated mine.

The simulator part of the programme has been especially successful. Here, the trainee operator gets exactly the same look and feel as with the real machine. All procedures such as start-up, drilling, tramming, drill plan handling, and positioning are performed in exactly the same way as with the real machine, giving a totally realistic experience (Figure 9).

Another important advantage is that these simulators are

Figure 9. Atlas Copco simulators provided for training the operator to use the machine safe and properly

capable of producing and analysing performance data that enables trainees to improve their own performance and compare results with fellow trainees in groups. This not only leads to higher standards but is also a fun way to learn. Trainees can also go back and repeat any aspect of their training at any time, either to refresh a specific skill or to improve on weak areas.

The range of such training simulators available on the market is continuously expanding and, in time, will encompass most types of equipment for both underground and surface mining, as well as construction equipment. In the future, as learning devices such as these become more widespread, mining companies will be able to train new operators to a high standard with a minimal impact on their day-to-day operations and resources. And this, in turn, will impact on their flexibility, productivity, safety, and profits.

Automation

The driving force for change is the global quest for improved safety, along with the need to boost efficiency and productivity in response to fluctuating commodities markets.

Automation is the ideal and obvious solution for mines where production processes are exceptionally deep, unusually difficult to access, hazardous, or repetitive.

Automation enables mining companies to keep their personnel safely out of harm's way while simultaneously reducing manual, repetitive work and laying the foundation for a modern, safe, and productive environment for the future.

However, although there are plenty of examples of fixed underground plant that has been automated for many years, including pumps, crushers, and hoists, automated mobile mining equipment is not yet commonplace.

Deep mine safety

The focus on automation is, however, growing, especially when it comes to drill rigs and loaders, and automation is gradually becoming more widespread as mines go deeper and new mines are opened.

For example, longhole drill rigs are being used, together with remote control systems, to enable operators to do their jobs well outside the drilling site, and automated LHDs are being used in the entire production cycle. This includes teleremote mucking, autonomous tramming to the dump site, auto dumping and returning autonomously to the drawpoint for the next loading cycle.

Similarly, there are also trucking applications whereby the trucks are loaded by LHDs or by chutes and trammed autonomously to the dump site, and then back again to the loading area.

Real-time impact

At the same time, these automated systems provide real-time information to management and supervisors, enabling accurate planning, scheduling, and process measurement.

However, while many of the functions of today's drill rigs and loaders are prepared for automation and autonomous operation, many other key operations of the production process such as scaling, shotcreting, and rockbolting are still largely performed with manually operated machines.

As a result, very few mines can claim to have implemented automated processes on a large scale, and consequently, is likely to be many years before the vision of the fully automated mine becomes a reality.

To a great extent this gradual pace of development is understandable. Automation is not just a good idea; it requires considerable investment, planning, and patience in order to reap the full benefit. Nevertheless, wherever mines have made a strategic decision to automate, the outcome has been mostly positive.

A good example is the iron ore mining company LKAB in northern Sweden. Its mines at Kiruna and Malmberget are models of modern mining with high levels of automation in production drilling, loading, and rail transport.

For many years, this company has been working together with its equipment supplier Atlas Copco to develop drill rigs and systems that could be controlled from a position well away from the mining area, and today this is a reality (Figure 10).

In fact, much of the automation technology that is available to the modern mining industry today has been pioneered by Atlas Copco in collaboration with mining companies. This includes everything from computerized control and guidance systems on large underground drill rigs and loaders to remote control and satellite hole navigation systems for surface drill rigs.

At LKAB's Kiruna mine, the remote controlled longhole drill rigs are also run during night shifts in automatic mode, entirely without supervision. The mine states that production has increased by more than 40% since automation was first introduced in the mid-1990s, and the number of drill metres achieved using this method now exceeds 1 million per year. There also has been substantial growth in productivity, since two or three operators can remotely control six to eight rigs. During the night, these rigs are capable of continuing without any form of manual supervision.

Meanwhile, the rigs' RCS system (Rig Control System), which makes all this possible, has become the standard platform for fully automatic operation and all automation applications.

Prerequisites for success

In order to realize the full benefits of automation, it is important that mines use equipment that has been specifically designed for automation, rather than manually operated machines that have been adapted.

Figure 10. Six drill rigs operated from one central control room at LKAB Malmberget

With an automated process, emergency repairs are extremely disruptive since they entail closing off a section of the mine. If acute repairs were to be performed, this would disrupt the planned production time for the LHDs, and it would also be difficult to plan other activities in the same area around the repair of automated machinery.

In addition, mine planners should consider automation and plan for it from the start of mine development. This will allow only certain areas to be closed off, and will help to keep downtime at a minimum. Mining areas that are specially designed for full-scale automation are clearly those that stand to reap the biggest rewards.

It is also interesting to note that wherever automation has been adopted on a large scale, the role of the operator has shifted towards that of a supervisor. He/she now sits in a control room and is empowered to run multiple machines by having a complete overview and complete control of the operations. It is important, however, that the operator makes sure that maintenance is performed according to plan to avoid breakdowns.

As most of the tonnage in tomorrow's world will be extracted using mechanized equipment, it is reasonable to assume that automation will continue to grow. Moreover, when it comes to establishing new mines in remote areas where it is difficult to recruit personnel, automation may be the only viable option.

Another major benefit is that a high degree of automation will almost certainly improve the industry's image as a safe, healthy, and interesting workplace, and make it easier to attract new recruits.

The initial costs may be high and hard to justify at times, but the overall saving is substantial when all cost parameters are taken into account. Beyond this, the advantage of being able to remove people from the actual mining areas is substantial terms of risk reduction.

References

MINE SAFETY AND HEALTH ADMINISTRATION. 2014. metal/nonmetal fatalities for 1900 through 2013. http://www.msha.gov/stats/centurystats/mnmstats.asp

NORD, G.E. and ÖSTBERG, A.2011. Setting up the new high quality standards for pre-grouting drilling in tunneling. *ITA-AITES World Tunnel Congress*, Helsinki, Finland, 21–26 May 2011.

SWEMIN (Swedish Association of Mines, Mineral and Metal Producers). 2013. Occupational injury report. http://www.svemin.se/vara-fragor/arbetsmiljo_3_1_1/branschstatistik

SWEDISH WORK ENVIRONMENT AUTHORITY. 2010. Berg-och gruvarbete. Swedish Working Environment Regulation for rock and mine works. 2010. AFS2010:01. June 2010.