Many are calling for improvements in development productivity, particularly in hard rock. As we go to press in a market maelstrom there is still great confidence in the industry. The fundamentals for soaring demand remain and the current problems are just slowing exploration and development, which will lead to further shortening of the project pipeline, which in many commodities was still not what it should be.

We are going to see more underground mines, we know this. Developing them faster, at the appropriate time, will be important. Yet, in 2005 Atlas Copco reported that development rates had increased on average by only 24% in the previous 25 years.

At Massmin in June, Gunnar Nord of Atlas Copco Rock Drills presented Faster drifting in mining, some aspects. He contends: “A long term drifting capacity of some 10 m/d is a fully realistic advance rate and this without novelities but just introducing technology of today.”

Nord picks out nine parameters that can be worked on to improve advance rates. These are:

- The shape and size of the opening
- The length of the round (either ruled by stability or momentum)
- Support and water handling approach
- Scaling
- The number of activities in the excavation cycle
- Demand on labour and management and methods of remuneration
- Choice of equipment
- Safety regulations
- Communications underground.

Nord says: “It has long been believed that the smaller the tunnel is, the faster the excavation will be. This is not true. Shape, support measures, excavation sequence and equipment used are the input parameters when establishing the most effective tunnel size with respect to excavation speed.”

When using drill and blast for mine development, there are a number of sequential operations at the face – generally seven. These are drilling, charging and blasting, ventilation of the face area, scaling, mucking, bolting, and lastly shotcreting. Each of these operations requires that equipment be mobilised and then demobilised. The time required for each of these operations remains pretty much the same irrespective of the length of the round. So, longer advances per blast will increase daily rates, cutting down the number of mobilisations/demobilisations per day.

Nord concludes that there are things to learn from the approach of civil contractors on drill and blast tunnelling jobs. Önnerlöv’s SimMine Development Package software aims to optimise resource planning and scheduling of underground development. It is an easy-to-use and powerful software to plan, simulate and evaluate the development process in underground mining. With this program, mines can set up their layout, fleet and resource configuration and plan by setting rules and restrictions. A mine can then simulate the development plan to see if it can be completed on time within budget. The result from simulation will show developed metres, current bottlenecks, costs etc. It is also a tool to investigate ‘what-if’ scenarios, such as shift changes, machine changes, number of workers etc, and how all these changes affect the results.

The program has just been released, but Önnerlöv has used the tool on several projects already. These cases have covered everything from estimating the amount of equipment required to optimising resource planning and scheduling of underground development.
needed, to raising the annual development
metres and where the next bottleneck would
be, to determining what shift schedule should
be used and the size of the crews on
development, and their resource pool. At a
recent project in Australia, SimMine was
helping Newcrest Mining with its Cadia East
project to determine what size development
fleet was needed, how to optimise haulage
and how to prioritise development of drifts in
order to ensure that all the necessary
development is completed on time so that
extraction of ore can start according to plan.

Safety and productivity are key words. For
this reason, simulators are becoming widely
used by the industry, and that includes
development drilling. Atlas Copco has
introduced a portable simulator that is now
being offered to reduce the cost of training
potential users as well as for job safety. By
using a simulator, potential users learn how to
use a drill jumbo without having to physically
be in the machine itself, allowing the drill to
keep working. Training in difficult and
dangerous manoeuvres is done within a safe
and controlled environment, without danger
to the driller or other workers.

The simulator can be used within several
areas of instruction. A skill evaluation can be
performed for operators who are new to the
company. Familiarisation for operators who
have previous experience with other drills can
benefit from simulator training. Lessons for
future operators can use training exercises to
set their specific level of ability and knowledge.

On-going training in correct machine operation
procedure can be given to existing operators.
The simulator can be easily transported
where and when it is needed. The cabin is a
replica of the real one. It uses the real
machine’s hardware (controls, console and
communication modules), enabling the trainee
to achieve a handling feeling nearly identical to
the real machine. Complete bi-directional
communication with an authentic console
permits configuring, modifying and visualising
parameters from within the console. A high
quality plasma screen offers an impressive
sensation of realism and immersion. Real world
sounds of the machine and drilling process are
heard and it has a virtual environment based

The mining industry is much safer today as a result of
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on the digitalisation of real pictures. Navigation and calibration exercises are included and software is available for updates.

**New jumbo**

Terex® says its new Reedrill MK7 electro/hydraulic jumbo “offers ease of maintenance and outstanding versatility. This enhanced model was developed using input from mining companies themselves, resulting in a new design and increased efficiencies.

“The MK7 is the only jumbo drill on the market with an option to convert it from a conventional jumbo drill to a computer-assisted or fully automated machine. In computer-assisted mode, drilling patterns are programmed in and the computer determines the most efficient path, sets and holds the drilling angles and calculates the footage drilled with precision accuracy.

“While an operator is still needed, a computer-assisted machine can determine the best pattern layouts, penetration rates, and mapping of the drifter—all of which improve production and reduce manual set-up time.”

The HPRH 3818 hydraulic drifter provides high-performance drilling with low operating costs thanks to fewer moving parts than competitors. Additionally, the drill has low energy needs. Other attributes include:

- Electric over hydraulic proportional valves—Smooth controls allow easy adaptation to computer assist mode and improve ease of maintenance; removing hydraulic valves from the operator’s compartment reduces heat and noise
- Variable displacement, compensated pumps—Hydraulic efficiency reduces energy loss
- Mercedes 904 Tier 3 engine—Fuel efficiency and mechanical accessibility offer added performance

Emulsion explosives have an important role to play in the process of making development faster and safer. Orica’s new MCU2200B is a simple bladder unit designed to deliver emulsion for shaft sinking operations through a delivery hose without the use of conventional mechanical pumps. Compressed mine air is introduced into the cylindrical tank and provides the motive energy to displace the explosive product from a rubberised bladder to the lube free loading hoses. The novel delivery hose has no requirement for lubrication, therefore no water tank, lubrication pump or water-ring is required and is capable of loading emulsion and AN/EP blends with accurate dispensing. This simplifies operation as well as reducing operating and maintenance costs.

The base unit offers a three-delivery hose setup with pneumatic remote controls. The MCU2200B comes with an improved two-way forklift slot design to help with picking up the unit from any side. A four-point lifting beam is also provided for overhead lifting.

**Mechanical cutting**

At a recent seminar in Burlington, Ontario, Canada, Kari Parvento, President, Sandvik UG Hard Rock Mining, said “we will see more mechanical cutting” in hard rock mining. In August (p8 on) we reported on the success of a Sandvik roadheader at the Fresnillo silver mine in Mexico. Another positive example of this was provided by Luis Zepeda, Project Manager for Haldeman Mining at the HMC copper mine in Chile.

HMC has an ‘exotic’ copper orebody, a mineralised conglomerate. The compressive strength of this conglomerate is 5-10 MPa, and it is particularly important to keep this mineralised material (1.5% Cu) from water, in which it turns to slurry. The roof above has a strength of 5-10 MPa and the floor is considerably harder. Mining in this deposit employs rooms and pillars up to 5 m high. The mine was designed for a daily production rate...
of 3,000 t but this is not being achieved with batch drill, blast and LHD mucking. The current underground output of 1,600 t/d requires 16 mining faces.

So, HMC is currently implementing a change to headroom mining, with a great deal of test mining already completed. The aims are, firstly, a major increase in the speed of advance to 15-20 m/d for each machine. This mechanised cutting will reduce the number of miners required in each mining section. It will have reduced impact on roof and sidewalls. Ventilation will be improved because there will be no explosives used and one rehandling stage is reduced as the headroom loads directly into mine trucks, cutting the requirement for LHDs.

Following on from the test mining HMC has ordered a Sandvik ATM 105-1C roadheader – 18 m long, 3.5 m high and 4 m wide. This machine is equipped with its own bolt, which will also speed operations. Zepeda reported that the mine expects to achieve a cutting rate of 80 m³/h.

In test mining, the effective cutting hours were just 3.5 h in a 12 h shift. This was low because of operational and support problems but the mine is confident that significant improvement can be made. The instantaneous cutting rate was 45 m³/h, and a net cutting rate of 82 m³/h is predicted. Pick consumption was just 0.037 pick/m³, compared with the 0.1 pick/m³ predicted. The hourly advance rate was 1.3 m and production 108 t.

This translates to 750 t/d per machine. However, continued process improvement is expected to raise this to 1,000-1,200 t/d, at a cost of about $15/t, and the latter should continue to fall, Zepeda commented. He said the trials had been very positive and will continue to the end of the year.

**TBMs in block cave**

Block caving requires the development of an extensive extraction level below the orebody for the block of ore to cave and the material extracted. An undercut of sufficient extent must be mined so that the rock mass cavities. Since large block cave mines require an extensive tunnel network to provide access to the undercut and underlying production level, ventilation reticulation and ore transport, they offer opportunities for the use of Tunnel Boring Machines (TBMs).

Downing et al, authors of a paper at last year’s RETC¹, note “traditional mine development uses tunnels that are 4 to 6 m in span and generally of square or rectangular profile. Common mining equipment can advance tunnels of this size as a single face at typical rates of 5 to 7 m/d, slow by the standards of TBMs. Since very little typical mine development equipment (drill jumbos, bolters etc) is used once production begins there is an opportunity to look at more efficient methods of tunnelling during the construction phase. TBMs become competitive under these conditions.”

All of the ring drives surrounding the orebody footprint offer opportunities for TBMs provided horizontal curves are designed appropriately. And, large mines of this type are likely to require numerous headings of the common 4-6 m size to provide sufficient cross sectional area for fresh and return ventilation, large conveyor belts and equipment movement. “Smaller numbers of large diameter tunnels (~10 m diameter) may offer capital and operating cost advantages since they reduce friction losses in ventilation (saving chilling costs in deep, high temperature environments) and allow a greater proportion of their cross section to be used for services such as water, power and compressed air. This presents a further opportunity for TBMs, as the comparative advantage over drill and blast in terms of advance rate will widen with larger diameter tunnels.

Lastly, TBMs are conducive to installation of life-of-mine ground support systems under the very high stress conditions encountered at the depths of 1,500 to 2,500 m likely to become common for mining in the future.

“To date TBMs have seen very little application in the mining industry.” One example of a TBM being used for the development of a block cave mine was San Manuel mine (visited by this editor). This was a relatively successful project.

“The number of block caving mines is likely to increase in the future and the mining industry is beginning to recognise that the ‘rock factory’ philosophy has merits for large, long-life mines. In this philosophy, design and construction standards are based on the requirement to move large quantities of ore at the maximum speed and minimum cost possible. This requires maintenance-free roadways with surfaces that minimise equipment wear, high quality ventilation, and services that can achieve levels of availability common in industrial plants. TBMs, which have achieved these goals for transportation and public infrastructure projects, have a potentially bright future in this arena.”

Lok Home, President, notes that The Robbins Company has, over the past 20 years, made numerous proposals to apply TBMs for mine development. “To date we have only been fortunate to have four mines use this technology and apply it to mine development. Three out of four of these applications can be deemed a success. Despite the fact we can demonstrate that daily advance rates in a 7 m diameter heading, for instance, can average up to 30 m/d, we cannot seem to generate significant interest in the mining community.” He explains that with current mine layouts the need is for a much more mobile and simplified system. “However, with our history and experience of developing the mobile miner we are not optimistic such a machine can be developed in the near term.

“We believe the correct approach is to integrate current TBM technology into practical applications for mine development and work toward a compromise in mine layout and standard TBM technology. TBM manufacturers can design componentised TBMs that can be moved down relatively small compartments and shafts, turn relatively short radii and erect ground support simultaneous to boring. Such machines may
not achieve the high performance as seen on civil projects but can consistently turn in 10 to 15 m/d advance rates. “The big progress at effective adoption of this technology can only be made at the initial mine development stage. It is unlikely it will occur through a typical mine research and development program to incorporate TBM technology. “With some large diameter TBMs producing plus 5,000 t/d there seems to be the possibility to use such capacity as an outright mechanical mining machine. This capacity can be achieved with an operating crew of less than 100 personnel total crew. “Furthermore, there exists the potential to use TBM technology in the mine rescue arena. This is especially so in coal mines where the rock is relatively soft and advance rates of plus 10 m/h can be realistically predicted. “He concludes by noting that compared to civil tunnels, mine development tunnels or m/y of tunnel completed in mining surpasses the civil distance by a factor of 5 to 1. “With this large volume of mining tunnels it would appear this should be a natural target market for TBM suppliers. However, history has proven the cost to enter into this market surpasses the financing capacity of today’s suppliers and, therefore, a partnership or an initiative from the mines must occur if TBM technology is to be integrated into mine development. “A main beam TBM – potentially the fastest way of driving in hard rock

Managing change
Knights et al provide case studies demonstrating how systems engineering methods have improved “underground development rates across a variety of projects and using a variety of methods.” They summarise that:

- Northparkes mine in Australia achieved a 56% improvement in cycle times using Lean (Lean manufacturing has its roots in Toyota developed from the 1950s)
- Lean software used on the Channel Tunnel Rail Link project in the UK increased production reliability from 70% to 80%
- Six Sigma supported application of emergent technologies that resulted in single heading tunnel rates over 8 m/d at Newcrest’s Cadia East mine in Australia (60% above the Australian benchmark of 5.3 m/d)
- In Canada, at Kidston mine, Six Sigma saw development m/manshift increase by 25%. They conclude that “the repetitive cyclic nature of underground development [is] well suited to systems engineering methods. “More reliable and faster data capture and reporting was identified as key to sustained implementation of systems engineering. Faster and more reliable data also offers the potential to continually improve development rates by incorporating systems engineering methods into the system itself.”

Rapid support
In developing the access decline to the Cadia East orebody, Newcrest started stabilising cross-cuts using common grouted cable bolts. However, continuing development advance had to wait until the cable bolts had reached their defined load-bearing capacity. “To speed things up, DSI Australia proposed an adaptation of its Hi-Ten Strand bolt. This bolt is anchored from the bottom up. At first anchorage is achieved in a length of 2 m by using resin. The HiTen Strand bolt is then tensioned to 250 kN, thus providing immediate stabilisation of the development area. Grout injection can be carried out

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immediately, or at a later stage. Thus, development can proceed immediately, independent of the grouting process and curing time. This helped Cadia East achieve its exceptional development rates.

Post-groutable Hi-Ten Strand bolts are especially suited for areas in which full resin encapsulation is impossible due to technical limitations or unstable rock layers. Using Hi-Tens considerably accelerates the installation cycle because grouting of the bolts is carried out independently of heading development.

The ground control component of rapid, safe development is an area which demands a great deal of focus. Historically, unless in extremely competent, low stress rock, the ground control function when compared to drilling, charging and mucking has been the most time consuming and, at times, the most hazardous.

“Underground mines are going deeper and deeper, into higher stressed and otherwise more challenging environments. Our customers have been clear in terms of their desire to develop orebodies for extraction with the highest priority on safety and speed, as well as productivity” explains Mike Rispin, Head of Mining for the Underground Construction group of BASF Construction Chemicals. “One focus of ours is on providing technological solutions for sprayed ground support, specifically in the disciplines of Sprayed Concrete (wet shotcrete) and Thin Spray-On Liners (TSL).”

Sprayed ground support, when properly applied, enables rapid and effective support of an underground opening while minimising exposure of the workforce and equipment to falls of rock. Also, as part of a well designed ground control philosophy encompassing complementary reinforcement as required, this approach can often be the best economic choice over the long term when considering durability, performance and reduced rehabilitation.

“The key to a successful wet shotcrete program is a holistic approach: concrete raw materials, admixtures and accelerators, QA/QC, logistics design, equipment, training and team commitment” elaborates Rispin. “Sprayed concrete has evolved over the last decade to where it is often the first choice of ground support for new mines as well as a desired ‘retrofit’ for existing operations with significant remaining mine lives.”

In this area as well, mining should benchmark some practices from civil tunnelling. In particular, the mining industry has tended to be conservative with regards to re-entry after shotcrete has been applied. “Over 10 years, the industry has progressively and safely moved incrementally with developments in technology and technique from waiting times in excess of 10 hours and miners are now, in certain jurisdictions, re-entering after one to two hours” adds Knut Garshol, Underground Technical Manager for BASF’s NAFTA region.

“Even though tunnellers have traditionally had quicker re-entry, the advent of Alkali Free Accelerators (AFA) has dramatically improved the strengthening characteristics of early age shotcrete over the previous standard of sodium silicates.” This has been particularly positive for re-entry times in mines.

BASF’s Meyco Equipment is developing an interesting approach to automation of sprayed ground support. The MEYCO Logica System consists of sensors and actuators connected through an industrial-grade BUS, a computer

MEYCO’s Logica System brings many advantages for spray application underground. It not only offers unmatched spraying quality with less dust and rebound due to correct spraying angle, but also a great improvement in operator safety and economy.

for the kinematics and an intuitive user interface with touch screen. These robots apply sprayable materials such as wet-mix sprayed concrete and sprayable membranes.

This technology enables an operator to guide the spraying jet in various modes, from purely manual to semi-automatic and fully automatic, within selected working envelopes. The fully automatic mode has been shown to be vital where conditions are extremely dangerous, where no operators are allowed in this part of the heading and also where a minimal layer thickness is required to achieve certain static capabilities.

Prior to the application of the sprayed materials, a laser scanner sensor measures
heading geometry and this information is used to automatically control the spraying distance, speed and the angle of the spraying jet to the surface. With a correct angle of application and constant spraying distance, a remarkable reduction in rebound and therefore savings in cost can be achieved, whilst simultaneously increasing safety through better overall control.

It is imperative that the first security measure reaches a defined minimum layer thickness in order to bear a predefined static load. With the substrate unevenness and poor visibility it is difficult to apply a minimum layer of sprayed concrete over the entire area. Under these conditions it can make sense to apply this layer of sprayed concrete using a fully automatic spraying robot so as to achieve the required minimum thickness.

Further, by being able to spray a defined thickness layer, overspray is also countered. The concept is to get the prescribed thickness of ground support specified without excess material being applied.

**Lower Mpa**

In soft rock, the 14ED25 is a recent addition to Joy Mining Machinery’s Entry Development product mix. Its ability to simultaneously advance the entry while installing roof and rib bolts yields increased productivity potential beyond the standard bolter miner configurations. It features a high power cutting mechanism and complementary machine mass to meet the wide ranging demands of full face gate entry or construction applications. OPTIDRIVE traction, independent rear conveyor drive, variable displacement hydraulics and enhanced roof drill components are more features of the 14ED25. The 12ED25 model will also soon be available for those high seam applications suited for this innovative cut/bolt technology.

Last June Bucyrus shipped its first 30M3 continuous miner for use in coal in the Western US, to Energy West. While the 30M series is used in coal in the east and midwest of the US, these machines have also been very successful in potash because of the machine’s performance in hard cutting applications.

The 30M Series ranges from the mid-seam 30M2 to the 30M4-NP, which is a high-reaching machine capable of operating in narrow roadways, the 30M3 for medium to high seams and the 30MB miner/bolter. Units have been placed in the US, Australia, South Africa, Canada and India. A 30M3 like the one shipped to Energy West weighs 70.3 t, has a total power of 697 kW and has a mining range of 1.6 to 4 m.

Wethead cutting technology is now available on the Bucyrus 25M series continuous miners. Bucyrus says: “the wethead concept is gaining popularity within the mining industry because of its advantages in dust control, noise reduction, operator comfort and visibility and a substantial improvement in bit life.” It also reports its wethead design is unique “because of the flexible split gearcase of the 25M series. Water passages are large and with the use of check valves, water is able to flow to the cutter drums through both the left and right gearcases or through a single case.”

Other key features of the wethead that will increase reliability and service life include a 51-mm thick drum shell, rifle drilled water passages through the shell, carbon-faced seals, corrosion resistant ports and components and seal cartridges that are accessible without opening the gearcase reservoir. Any water leakage is diverted to the outside of the gearcase so that seal failure will not damage the gears and bearings. Also, with the proper maintenance, the cutterhead can be run wet or dry.

Testing has revealed that the Bucyrus wethead design can reduce dust by as much as 60% in the operator’s area and by over 50% behind the air curtain.

Bucyrus wethead technology is now available on the 25M2 and 25M3 models, and will be available on other continuous miners in the future. IM

**References**

2. B. Nord, Faster drifting in mining, some aspects, 5th International Conference and Exhibition on Mass Mining, Luleå, Sweden, June 2008