The need for mechanization of stope drilling

The S.A. gold mining, and to a lesser extent, platinum mining industries are currently facing a number of challenges that threaten competitiveness, and in some cases...survival:

➤ Deeper mining—bringing increased danger of rock falls, higher costs, lower productivity and a hotter working environment
➤ Low commodity prices coupled with rising costs of employment
➤ Lower rates of improvement in productivity than mines in competing countries
➤ Drillers have a strenuous job (see Figure 1), one that does not appeal to younger workers—to the extent that the average age of drillers on a mine sometimes exceeds 45 years. AIDS is also threatening the skills base and ability to perform strenuous work

➤ Increasing pressure from unions and employees to improve working conditions and reduce the risk of fatalities, injuries and operational illnesses.

Drilling of blastholes is fundamental to underground mining; the effectiveness of drilling and blasting can greatly influence the profitability of a mine; it is also an operation where workers are exposed to significant risk of death and injury from rockfalls and rockbursts.

There is, therefore, a desperate need for simultaneously improving the accuracy of drilling, mining productivity and operator safety and working conditions.

Various methods of mechanized stope drilling have been tried but have generally proved to be unsuited to the combination of difficult mining conditions; a 0.8 m to 1.4 m working height is typical, it is hot, humid, corrosive and equipment is subjected to harsh handling. Workers are also often unskilled in the use of machinery.

Overview of the Novatek stope drilling system

Bar and arm drill rigs have been available since the days of early pneumatic drills (see Figure 2); they were however, inflexible and inherently limited in their capabilities. Novatek revisited the concept and applied a number of patented improvements to provide a system that is workable within current mining practices.

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The Novatek drilling system was designed as an ‘appropriate technology’ to suit the reality of S.A. mining—confined working conditions; a hot, humid, corrosive and dusty environment; relatively unskilled mineworkers, ore-bodies that are undulating and intersected by faults.

The Novatek drill rigs (see Figure 3) interface with the props both as a means to support and position the drills as well as a reference from which to accurately drill. Thus, installation of the drilling system requires little additional work. A series of beams are attached to clamps on the props and they interlock to form a continuous beam along the working face.

The drills and feed booms are mounted onto the beams using a saddle on rollers, allowing the operator to slide the drill along the beam, drilling at the specified burdens and with the correct hole orientations. The operator is positioned well away from the face, behind the drill and under supported conditions.

The attachments and beams allow for variation in the orientation and spacing of the props to account for undulating conditions and misalignment between props. Following completion of drilling, the rig is disassembled and stored in a back area.

The system is formed from individual modules (prop collars, traverse beam, drill feed) that are quickly and easily assembled and are individually light enough to be moved and installed by hand.

The radar plot in Figure 4 compares hand drilling, typical footwall-rail-mounted rigs and the Novatek rig against various attributes, 5 being the best score in each. The most generally suitable design encloses the largest area. Whereas the Novatek rig is not necessarily the best performer in each category, it performs well in all aspects. The rig system provides much greater drilling accuracy with little loss of flexibility. The advantages are very apparent from a cost-benefit viewpoint.

From the above, it is clear that the system is simple in terms of its components and operation and it should not pose a great challenge in respect of the technical aspects of implementation.

Achievements of the Novatek stope drilling system

Although the system is still evolving into a better and easier-to-use system, it proved from the start that it was able to provide the benefits of accurate drilling, mining efficiency and safety in a simple, easy-to-operate package.

The system has been tested on over 25 shafts in southern Africa, and over 350 units have been supplied. Of these, approximately 70% are in regular use or in the process of being implemented. The remaining 30% represent cases where trials and implementation have been ineffective and equipment is not in regular use.

Results on all mines where the system has been tested or is in use have shown without doubt that the system provides the means to:

- Drill accurately. Typically, sockets are clean or less than 10 cm, even when the hole length greatly exceeds the stope width (advances of 1.5 m are achievable in stope widths of 1.0 m or less). In many instances, the rigs have been used in conjunction with improved detonator systems such as EDDs and shock tubes, however, good results have been achieved with normal fuse igniter cord
- Drill up to 50% faster due to the in-line thrusting
- Reduce drillers by up to 50%, dependent on mining conditions. This provides the opportunity to re-deploy drillers to increase raise line utilization, etc.
- Drastically reduce worker exposure to rockfalls and rockbursts by moving workers 2 to 3 m back from the face and under good support
- Greatly increase mining efficiency, reduce costs, and improve productivity. A study within an Anglogold mine showed that a 10% to 15% reduction in stoping costs was possible
- Face shape, stope width and hangingwall condition are greatly improved.

One contractor introduced the Novatek system on a 30 m panel and gully in a gold mine, achieving:

- A reduction from 8 drillers and assistants to 3 drillers
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Figure 3—Components and nomenclature of the Novatek drill rig

Figure 4—Comparison of drilling systems using semi-quantitative attributes
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➤ A production rate of 19 m²/stope member was increased to 40 m²/stope member.

These results show the potential of the system. However, it has been a frequent experience that they are often not sustained, especially when equipment is operated by mines rather than contractors. It is clear that the technical capability of the system is not the issue, but rather the implementation process.

Implementation experiences

On initial introduction of the stope drilling system, Novatek underestimated the implementation problem. We saw that jackdrill operators could be retrained to be competent within 2 days, good results were achieved quickly, and the system had obvious advantages to all. We expected that the buy-in would arise naturally. Typically, the first week of a trial produced happy operators who liked the ease of use and were less tired at shift-end, and miners who saw the positive results in face advance and stope width reduction.

However, the second week suddenly produced operators who were fearful of job losses and in some cases refused outright to use the equipment. Miners and shift bosses also started to question what was in it for them—more advance only meant a better bonus as long as their targets were not revised. The labour issue proved beyond the resolution of middle management and it was usually easier to leave for someone else to address. Novatek’s involvement on the trial managed to keep the project going, but the core issues remained unresolved.

Subsequent attempts by Novatek to formalize the process were only partly successful, due largely to an ignorance of the importance of correct implementation by mine management.

It became clear that rollout would only be successful if it was tackled in a more formalized and rigorous manner, by suppliers in closer partnership with the industry. A study was undertaken by Novatek and Anglogold TDS to review the situation, determine the real problems and provide a plan of action.

Why certain trials and implementations failed — separating the symptoms from the real causes

A typical symptom on struggling rollouts is that the supplier is blamed for poor service, the equipment is reported as unreliable and unrealistic demands are made of the supplier. In many cases suppliers are expected to do the work of the mining personnel. Deeper investigation usually shows that the supplier is being unfairly blamed.

To determine the true causes, the study compared actual experiences within Anglogold, other mines and contractors. Successful and unsuccessful rollouts were compared with a normative implementation model (Figure 5).

The successful projects closely followed the normative process, either through the active effort of a champion, or naturally as a result of the management and users all having aligned objectives and all deriving benefits. These were also strongly characterized by clear objectives, targets for performance and reporting against these objectives.

The failed projects had unclear or contradictory objectives, ill-defined responsibilities, minimal sharing of benefits and consequential lack of buy-in. Reporting focused on reasons ‘why not’ rather than on hard results and actions. It also became clear that it was not sufficient to get most of the steps right; some enabling factors such as clear objectives, responsibility and buy-in are essential. Other negative or ‘disabling’ factors, such as job-loss fears could totally derail an otherwise perfect process.

Where a strong champion existed, however, weaknesses could be addressed by the mine and their persistence resulted in increased success. Unsurprisingly, without a champion taking an active role, the projects were allowed to slip off the radar screen.

Further findings of the implementation study

Some more detailed issues and shortcomings are summarized below.

Insufficient top management involvement, no monitoring and no control system

➤ Mandate—Little top management input, no proper objectives set, no reporting system, ineffective actioning of key success factors and potential project killers

➤ Objectives—are they clear and appropriate, is the mining cycle kept in balance (can extra advance be cleaned)? Are the objectives consistent with the micro, macro and mega situation? A comprehensive feasibility study should be a precursor to any significant change in mining method or technology

➤ Responsibility and accountability—No single mine responsible person or champion; creating the opportunity for excuses due to other responsibilities, etc. A lack of focus

➤ Incentives and buy-in—What are the incentives and benefits for the mine, the management, supervisors and workers? Does everyone share in these and do

Figure 5—Key implementation steps
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they believe and trust each other? Who stands to lose? A lack of buy-in is probably the greatest threat to the project.

► Communication—Objectives and intentions are often not clearly communicated nor discussed with line management and workers—increasing suspicion and reducing co-operation.

► No formal reporting on hard numbers—No feedback to mine management, or acceptance of woolly comments and redirection of blame. No concise reporting against objectives (e.g. ‘Our target is 18 m advance per month, we achieved only 16 m advance this month due to tramming delays, we are rescheduling tramming to achieve the target!’).

► Perception of the technology as ‘unproven’—Although the technology has already been proven on other mines, projecting a less than positive or unsure management stance creates the perception that the mine are guinea pigs for the supplier’s product testing—and the expectation of free maintenance and service. Ongoing product development and improvement should not be mistaken for research.

‘Throw it over the wall’ implementation

Our experience is that the supplier’s presence during a trial generally masks underlying mine problems. The supplier naturally wants the product to be successful and plays a co-coordinating and troubleshooting role. Once their personnel are removed or activities expand on the mine, the problems remain unsolved.

Hiccups during trials are often dismissed as teething issues and are not adequately dealt with.

At the end of a trial, the decision to proceed with rollout on the mine:

► Seems often to be made on gut feel and limited data, but without knowledge or proper consideration of the underlying weaknesses and unresolved issues.

► Or, if it is delayed due to lack of clear success, then the project starts to drift sideways and dies slowly.

Specific deficiencies are:

► ‘It is not my fault!’—Empowerment of the production management must result in no-excuses reporting. Problems must be addressed by the responsible person.

Roles of the mine and the supplier must be clear.

► Uncordinated training—Suppliers train the mine trainers, but they are often not used The supplier is often expected to train each new set of operators (for free).

► Crutches—The supplier service staff are often expected to organize everything—on numerous panels. Suppliers should be there as observers, trainers and troubleshooters—not as gophers. When the supplier withdraws, the project shouldn’t come to a standstill.

► Free service—Suppliers are often expected to provide full-time service over a long time period and at no charge. This is uneconomic and also does not force the mine to take ownership; it is in fact a symptom of lack of buy-in.

► Inaccessible infrastructure—the mine systems for underground stores, exchange and repair of equipment are often not properly used, making repair turnaround times long.

► Maintenance free!—Maintenance contracts are not put into effect up-front, or are delayed for many months. The reliability of equipment and presence of the supplier service staff may mask this problem during pilot trials. After a while when equipment needs repair, it does become a major hassle to the mineworkers.

► No loss control—Equipment abuse and neglect is usually not followed-up on the mine. Product reliability is again often wrongly called into question.

Mining contractors are more successful

Successful rollouts, largely by contractors and a few mines, highlight the following differences. The contractors have:

► Clear objectives—usually translated into commercial benefits. That’s their bread and butter they are playing with!

► Taken ownership

► Clear responsibilities

► Performance is the only job security—no excuses

► Know the results they have achieved and market them to expand the customer base

► Close supervision, quick feedback, and quick solution of problems

► Contracts for maintenance and underground service

► Focus on balancing the whole mining cycle—to get regular daily blast

► Minimal red tape.

The role of top management

Top management have a pivotal role in driving any rollout. They, through their role, level of involvement and subconscious actions create perceptions within their subordinates of the importance of the project and their expectations.

We have isolated a few key areas where top management may go wrong:

Define the objectives and the economic value to the mine

Nothing directs action better than a clear and achievable objective and a quantifiable value. It also ensures that a feedback loop is put in place and that problems are put into perspective. If the gain is large enough, the effort to address a problem is put into sharp perspective.

More advance/blast may actually lower production

The benefit of accurate drilling means that the tonnage produced by blasting the same length round may easily be 20 to 30% greater. This may already put pressure on the existing ore handling capacity. However, many mines are tempted to...
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drill even longer rounds without changing the mine layout, with the result that the ore handling system may be overloaded and the mining cycle is disrupted. Suddenly, a sporadic 1.8 m round is less effective than a daily blast of 1.2 m.

Do not ignore the gullies

Faster rates of advance on panels obviously requires faster gully advance. If ignored, panels quickly catch up and stoping must stop. Sometimes, miners run the panel with a lagging gully and quickly lose the benefits of the drill rig as the face shape curves. Drill rigs are also available for gullies, raises, etc.

'Trial' or 'Test' means that failure is an acceptable outcome

Calling a rollout a ‘trial’ or ‘test’ sets it up for failure. Subordinates know that many reasons can be found to justify failure.

Banish negativity; the mental attitude must be positive, that success is the only possible outcome, so that actions are directed towards making the project work. Call the rollout a ‘project’ or ‘product rollout’.

The best man shouldn’t get the job!

In respect of equipment trials, conventional mining wisdom said ‘Test it in the worst situation with the worst crew—if it works there it will work anywhere’. Usually, this was the kiss of death for a project.

This paradigm then shifted to ‘Use our top man for the job’ by more progressive managers. Our experience has shown that the top man is not the right man. He is usually the one with the best production figures and on whom the mine depends. He is often overloaded already and has much to lose, both financially and status-wise. The result is usually an unwillingness to change or improve on work practices and a lack of attention to the project.

We recommend that competent, but average-performing managers and crews are used. They have little to lose, but a lot to gain.

Use a dedicated person to run the project

Usually a senior mine overseer has to take on the project in addition to their other responsibilities. We strongly recommend at least giving him an additional shift-boss to ease his burden. The additional cost is negligible compared to the value of using the rigs properly and the opportunity cost of failure. It also sends a clear message that management are serious about the project.

Put a feedback loop into place

Without measurement nothing gets done. Also, there is no substitute for first-hand observation—especially on surprise visits. With a positive attitude and clear objectives, honest reporting leads to actioning of problems. Where a blame culture exists, there have been cases of ‘kill the messenger’ when Industrial Engineering monitors or suppliers report bad news!

A rollout model

The objective of the joint study was to establish and prove a framework for rollout of the technology on Anglogold mines.

Proposed role-players

The primary stakeholder is the mine; they should manage and control the implementation. The mine must also provide the infrastructure for mine training, transport, arrangements for maintenance, etc.

The supplier must provide initial training and ongoing service, as well as maintenance services.

We believe that the head office and union/s have important supportive and policy roles. We feel that they have an important role in respect of determining policy of how mineworkers should be motivated, rewarded, and to secure union buy-in. Individual mines may be unwilling to take bold steps for fear of creating precedents.

Recommended rollout process

In our opinion it is important that all parties are involved; the large-scale implementation of mechanization is accompanied by some very powerful vested interests and fears amongst affected personnel. Alignment of all interests is essential if full co-operation is to be achieved. A formalized and sequential process is necessary to ensure that all issues are effectively managed at the appropriate stage.

The basic rollout process is shown in Figure 5, with the following key steps.

➤ At the start of the project, the supplier should meet with mine management, champions and responsible persons to plan and execute the rollout.
  - Set clear objectives. This may require a feasibility study to determine the effect of mechanization on other production processes such as cleaning and support.
  - Establish baseline mining performance data (current methods), set target performance, record actual performances with new technology.
  - Appoint responsible persons, dedicated to the project.
  - Establish policy and practices with respect to performance bonuses, staff cuts or reallocation. Communicate these to all parties.
  - Action all key issues and barriers to success. An otherwise flawless rollout can be scuppered by a lack of buy-in; for instance, if workers believe they will lose jobs and have not been convinced otherwise.
  - Involve mine trainers in the initial introduction and for further training of crews and supervisors.
  - Ensure that a maintenance system is operative. Without service support, any product will fail.
Periodic reviews by management to ensure that the project stays on track. Unannounced underground visits are also necessary to see the real situation, warts and all.

- Follow an agreed rollout process with all parties/stakeholders.

➤ Once the project is under way, under the management of the responsible person, periodic critical reviews should be made. Include a cross-section of personnel—operators through to managers, head office staff, suppliers and unions. Adjust the rollout process if necessary and be cautious of dismissing problems as ‘teething troubles’. It is essential that mine personnel take ownership of the project and that the benefits become tangible to them personally. The supplier should be able to withdraw without the project faltering.

➤ Reporting on the project must be part of the normal mine management reporting system. Reports must compare actual achievements to targets, plus corrective actions. It is especially valuable to frame targets in terms of tangible benefits (e.g. R1 m saving in operating costs, 75% reduction in injuries, etc.). This tends to put problems in their proper perspective, psychologically making them easier to deal with.

➤ At the end of the introductory phase, it is important to measure and record the achievements, note the problems encountered and review the further rollout from a position of experience. An output of the project should be a report (with input by all parties) detailing:
- Results of the initial introduction project
- The recommended ‘framework’ for further rollout
- Recommendations on resources needed for a wider rollout within the mine.

Resources

We recommend that the rollout will be managed by the responsible M/O. In order to provide him with sufficient time, an extra M/O should be used to provide management of the usual production in the section or an extra senior-subordinate used to relieve workload. This is especially necessary in the early stages while familiarity with the system is being developed and rollout issues are being addressed.

As the drilling system is progressively implemented the project M/O will re-assume responsibility for the working panels.

The mine Training Manager, Services Manager and Commercial function must also be involved. In particular, sufficient mine trainers must be deployed for both surface training and underground follow-up.

The supplier’s responsible person should manage the supplier’s role on the site and advise the M/O as necessary. The supplier’s experience should not be underestimated; suppliers have specialist product knowledge as well as experience of good and poor rollout on numerous other mines.

Experience from use of the rollout model

After the model was developed, the rollout process was applied with greater but not absolute success. This improvement arose from a better and more considered approach to the rollout. Novatek, through a better understanding of the issues, have also been more effective in getting mines to address the rollout more thoroughly.

However, absolute success has been elusive, chiefly because the mines alone can solve the key issues relating to their workforces; bonus schemes and job loss policy being foremost. The appreciation that the rollout process needs active and concerted management from within the mine organization has also not fully materialized.

We recommend that mines should formally train senior personnel in change management skills. This will sensitize them to the problems associated with rolling out new technologies and the need for dedicated management.

Conclusions

The mines have themselves identified new technology as being necessary for their survival—the drilling systems discussed in this paper have proved their ability to deliver significant benefits and mines must now hold the door open to bring the technology in.

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