AUTOROCK RIGS FOR ROCKBOLTING IN NARROW REEF STOPES

By Frank Johnson and Donald O'Connor
Minova RSA

Abstract

The drive for mechanization of stoping operations on South African platinum, gold and chrome mines is favouring stope support by rock bolts rather than the traditional volume-filling support methods such as mine poles. Many of the stopes are less than two metres high and this is posing a challenge for the drilling of the rock bolt holes in the hard rock. The major mechanised mining equipment manufacturers developed low-profile fully-mechanised roof bolting rigs for this environment. Such rigs cost in excess of R1 million each.

An alternative approach has been followed by some local manufacturers, who developed small rigs incorporating stabilizing jacks and conventional jackhammer drills. With the same manpower, these mini-rigs achieve the same output as the fully mechanised rigs, at capital cost of under R30 000 each. Safety of the rock bolting operators has been improved as they control the rigs remotely, from under supported rock, while their noise exposure is also reduced and vibration eliminated. Since 2002, over one thousand mini-rock bolting rigs have been deployed in South Africa. They are giving consistent high output and have been fully integrated into the stoping operations on several large mines. Further refinement of the rigs and expansion in their use is continuing.

The design, development and operation of the mini-rigs are described and the results of trials and full-scale use are analysed.

Introduction

Between 2000 and 2006, platinum production from the South African mines expanded from 206 to 307 tonnes (DME, 2007). Most of this additional metal has come from traditional "narrow" reef stoping, generally taken to mean stoping in working places with a mining height of less than 1,5 metres. It is well known that narrow-reef stoping presents safety, technological and ergonometric challenges (Pickering, 2007).

In planning for the expansion, which is still continuing, the platinum mining industry realized that it could not simply continue with traditional methods of narrow-reef mining. Particular issues identified were:

- High labour-intensivity: caused by use of hand-held rock drilling machines, labour-intensive support installation and stope cleaning;
- Dependence on rock-drillers: this occupation is no longer an attractive one and there is a reducing flow of new recruits;
- Safety: most of the work is performed close to the new faces, where there is the greatest exposure to the hazards of falling rock.

In many cases the decision was taken to mechanise operations. Activities for which mechanized solutions were sought were:

- Face drilling
- Cleaning of broken rock
- Support installation.

This paper focuses on support installation in narrow-reef stopes. In the process of mechanization, the platinum industry was faced with an issue encountered by all previous mining mechanization programmes: mechanized mining demands easy access and traveling for the moving machinery. Support by elongates (poles) or packs restricts movement and has always given way to support by rock bolts. The same had to happen in the SA platinum mining stopes (Arthur and Taylor, 2004).

Even in non-mechanised stopes, face support by rock bolts can offer advantages over support by elongates and/or packs:

- Rock bolts can be installed more rapidly than elongates or packs.
- This increases safety as the workers spend less time under no support or temporary support;
- Bolts can be installed closer to the face as there is no need to leave a gap for the face scraper;
- Rock bolts provide a stiffer support system than timber elongates or packs, even with pre-loading;
- The fire hazard inherent in the use of timber support is eliminated;
- Rock bolt support requires the transport of significantly less volume and mass of material than timber support elements;

The advantages are manifest – but it has proven to be no easy task to implement rock bolted support in the narrow platinum mine stopes.

Rock bolting in narrow stopes

Rock bolting requires drilling a hole of suitable diameter and depth and then inserting the rock bolt (“bolt” here includes all type of bolts, including friction anchors). The drilling operation is the more difficult one and as a general rule, if a hole can be drilled, some type of bolt can be installed. However, the type of bolt may be constrained by the installation method and hole diameter, which can compromise performance in its geotechnical role.

Mechanised rock bolting is well established in two environments:

- In “large” excavations in hard rock mines and tunnels, percussion drilling is used, with fully mechanised equipment.
- In both large and small (narrow-seam) mines in soft rock, especially coal measures, rotary drilling is used, also with fully mechanised rockbolters.

The narrow stopes of the SA platinum mines fall outside of both established mechanised support environments. The hanging-wall rock is usually a pyroxenitic rock (van Jaarsveld, 2004) with a uniaxial compressive strength of over 120 MPa. In 2001 one of the authors experimented with rotary drilling in order to use off-the-shelf low-seam coal mining equipment but no suitable drill bits were found and the experiment was abandoned. It was concluded that percussion drilling had to be used. Percussion drilling has been chosen by all the major parties active in this field so far (Pickering, 2007).

Mechanised rock bolting in the SA platinum mining narrow stopes thus required the development of new equipment, combining percussion drilling with low height, so that rock bolting can take place in stopes as low as 1,1 m. Progress has been slow and success mixed (Pickering, 2007). The rockbolters that have been developed have high capital and operating costs. Capital costs of over R2 million ($280 000) per unit are the norm. Operating costs are high as the equipment is sophisticated and expensive to maintain while output (holes per shift) is constrained by slow speed of tramming between working places. Usually the mechanized rigs are operated by two operators, which is no saving over the rock drill operator and assistant required for a conventional hand-held rockdrill.

Given the problems in developing and using the fully mechanized low-height rockbolters, it is to be expected that alternatives have been sought. The most obvious has been to install rock bolts using the industry-standard pneumatic airleg-mounted rockdrill. This has the attraction of being well-established technology which is applicable to both non-mechanised as well as mechanized stopes. It does however suffer from severe difficulties:

- The operator must work under rock which is unsupported or supported by temporary support;
- The operator's position under the drill hole exposes him to the drill flushings, making the task unpleasant and undesirable. To alleviate the discomfort, the operators drill inclined holes. Effective rock bolt anchor length is reduced and both thrust from the airleg and rotational torque from the drill are lost in friction against the wall of the hole;
- The airleg-drill combination is unstable and not rigid.
- Drilling of small holes, which are needed for the best performance and lowest cost of rock bolt support is difficult to achieve;
- The operators work directly with the drill, exposing them to noise levels exceeding 105 dBa for extended periods;
- In stoping widths below 1,5 m high the free space above the drill available for insertion of the drill steel ("daylight") is small, requiring many drill steel changes. Airlegs are essentially impractical in stoping widths under 1,1 m high.

Semi-mechanised rock bolting

In 2001 – 2002 local technology developers saw the requirement for low-stope rock bolting rigs which could overcome the shortcomings of conventional rockdrill/airleg combinations and be available sooner and at lower cost than the fully mechanized rockbolters, then under development. Three types of rigs reached the stage of commercial sales and industrial-scale production. They were well received by the mining industry. By end-2007 over 1500 of the most common type, the "Autorock" drill rig, had been sold and are in service, with the number steadily increasing. One of the early large-scale users was Modikwa Platinum Mine, where the role of the Autorock drill rig in improving stope support has been described by da Costa and van Vuuren (2005).

The features of the Autorock rigs are:

- Use of standard rockdrills to drill the rock bolt holes and insert the bolts;
- Incorporation of the rock drill into a small frame with drill guides;
- Telescopic jacks to stabilize the frame between footwall and hangingwall. The jacks also provide a combined thrust of 2 KN, providing limited temporary support to the immediate hangingwall;
- An elevating jack to provide thrust for the rockdrill; and
- Remote operation from approximately 5 m away.

Since 2002 there has been ongoing technical evolution of the Autorock rigs which now represent a significant technological contribution to narrow-reef stope support in the SA platinum mining industry.

Description of the Autorock drill rigs

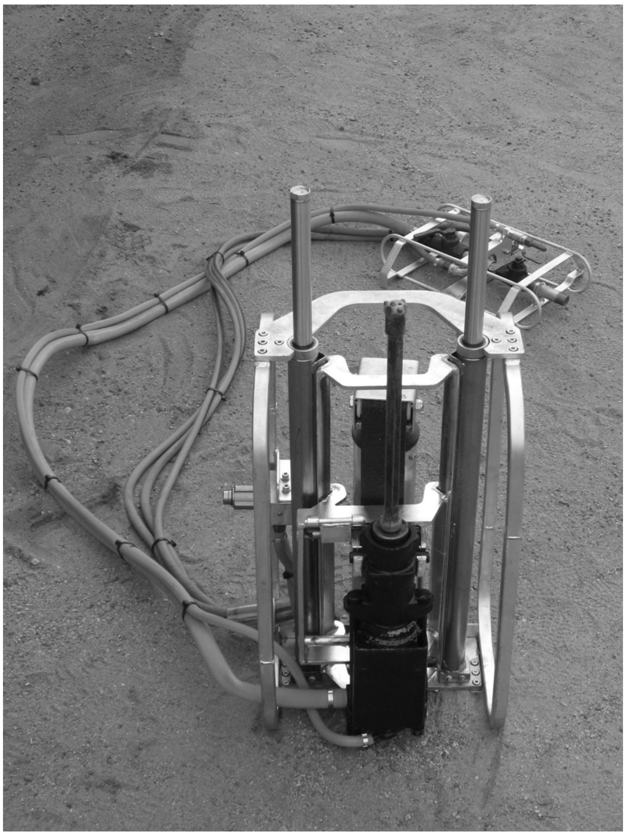
The Autorock rigs are supplied in standard sizes of 750 mm, 950 mm, 1100 mm, 1400 mm, 1800 mm and 2400 mm. The size refers to the height of the rig when fully collapsed. Selection of size is made according to the range of stoping heights on the particular mine. The stoping heights that can be accommodated by each size are shown in Table 1.

Table 1 – Rig selection for stoping width

Rig size	**Minimum stope height (mm)**	**Maximum stope height (mm)**
750	800	1230
950	1000	1555
1100	1150	1740
1400	1450	2290
1800	1850	2730
2400	2450	3330

A 950 mm mini-rig is shown in Figure 1. It has a frame of square-section steel tube, two clamping cylinders, an elevating cylinder and a remote control frame. Most users have wheels fitted to the larger machines make movement easier. The complete rig, with low-profile rockdrill and the control frame, has a mass of only 74 kg. If fitted with a pneumatic rockdrill, it is fed with normal mine compressed air and water.

Figure 1: Autorock drill Rig



In use, it is first raised into position where the hole must be drilled, then it is anchored into place by extending the pneumatic or water-powered clamping rods. The anchoring can be done from the remote control frame but it is more usually controlled from a valve on the rig itself. After anchoring, the operator retreats to the control frame which is in a safe position under already-installed support. Here he can control drilling of the hole. An operator must go forward to change drill steels and charge the hole with grout and insert the bolt. Spinning of resin grout, tensioning of the bolt and lowering of the stabilizing jacks are done remotely.

A two-man team will usually be able to install one rock bolt every eight minutes.

Hole drilling range

For installation of rigid, single-piece rockbolts the normal drill hole diameters are in the range of 28 mm – 32 mm. The maximum length of rigid, single-piece rock bolts is limited by the stoping width. Holes shorter than the stoping width can be drilled by using a set of progressively longer integral drill steels. This enables drilling of the smallest possible holes, which are preferred for resin rock bolting.

If longer anchors are required, coupled bolts or cable anchors must be used. Autorock drill rigs are regularly used for drilling of holes up to 11,5 m long for installation of cable

anchors. Coupled drill steels are used. The additional diameter of the couplings requires that the longer holes are larger: typical diameters are 36 mm – 45 mm.
Software has been written to optimize the choice of rig size and the drill steel lengths required to drill holes of specified length.

Conversion to Autorock drill rigs

The conversion process to Autorock rigs will be examined by way of a case study. The mine is a large platinum mine near Rustenburg in the North-West province of South Africa. Mining is on the UG2 reef, with mining heights from 1,5 to over 2 metres. Mining is conducted using a bord-and-pillar layout, with resin-grouted rock bolts as support in the bords. The bolts were installed with conventional hand-held rockdrills and airlegs.

During 2006 and early 2007 mine management became increasingly concerned with the safety and efficacy of the rock bolt support method. Their principal concerns were:

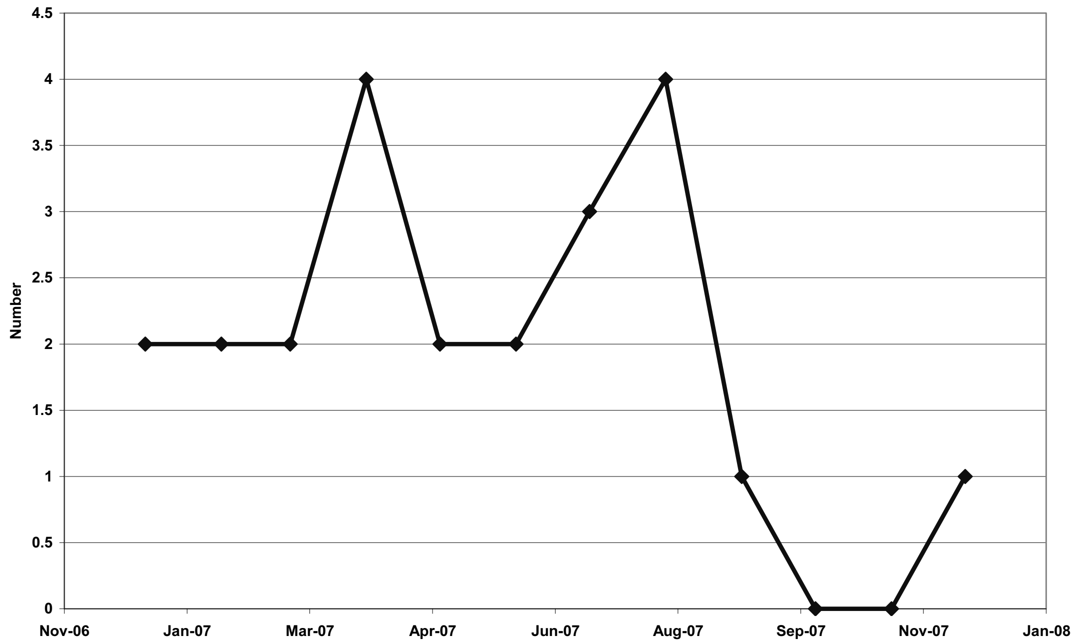
- Exposure of the rock drill operators to falls of ground while drilling the rock bolt holes;
- Rock bolt holes were often not drilled vertically, thus reducing their effective depth in the hangingwall.

The decision was made to change rock bolt installation from hand-held drills to Autorock rigs. Introduction of the rigs started in August 2007 and conversion was completed in November 2007, by which time 284 rigs had been supplied. The rigs are operated by dedicated crews, who were trained by the rig manufacturer's training staff. The conversion process also involved establishment by the manufacturer of a maintenance and repair workshop close to the mine. This workshop has subsequently been closed and maintenance is now carried out at the central workshops of the manufacturer, for better control.

At the time of writing (January 2007), mine management made the following observations:

- The quality of rock bolt installation was much improved, with inclined holes being eliminated, and the resin grout is better mixed;
- Face availability has increased as the installations are faster, enabling rock bolting crews to work ahead of the face-drilling crews;
- Safety has improved, with fewer fall-of-ground accidents, both at the face and during drilling of the rock bolt holes (Figure 2).

Figure 2: Reduction in Fall-of-Ground Incidents



Areas still receiving attention are:

- The high rate of accidental damage to the rigs, particularly from being blasted on or being run over by vehicles.
- The turn-around time for rigs sent in for repair is too long and the process is administratively complex.

Overall, the conversion has been judged a success.

Maintenance organization

As is evident from the example, successful operation of the Autorock rigs requires an effective maintenance and repair programme to ensure that damaged or worn-out rigs are quickly brought out from the working places, repaired and returned to service.

Several models of maintenance organization have been established:

- Mine performing own maintenance
- Supplier performing maintenance, on mine
- Supplier performing maintenance, off mine (usually centralized).

The model chosen is based on local circumstances such as remoteness from the supplier's workshop and general maintenance policy.

In planning for the use of the rigs, the average number of rigs which will be in maintenance must be added to the number needed in service, to ensure that no working place is without its complement of rigs. This number is normally about 30 percent of the total. Projected maintenance turnaround time can therefore influence the capital cost of the project. In practice, our observation has been that the critical path in the maintenance cycle has been processing of the order and invoice documentation.

To ensure that no blasts are lost due to non-availability of a rock bolting rig, one spare rig should be kept underground in each section.

The Autorock drill rigs will typically require maintenance every six months, at a cost of R3000. On mechanized mines where discipline over operation of mobile equipment is poor, the frequency and cost of maintenance is higher, mainly from collision damage.

Reflections on the implications of Autorock drill rigs for mechanization

Use of the rigs represents a retreat from the objective of full mechanization but offers the potential for the advantages of mechanized face drilling and stope cleaning to be realized. Where there is not the intention to mechanise face drilling or cleaning, the Autorock rigs are a mechanization step in themselves as they reduce the physical effort required to successfully drill vertical rock bolt holes.

Mechanisation is not an end in itself. Mechanisation was the path chosen to address industry concerns over safety, productivity and future ability of the industry to attract employees. The development of Autorock rigs has enabled industry-wide roll-out of stope bolting (which has safety advantages) and is an enabler of the other two aspects of stope mechanization (drilling and cleaning). Autorock drill rigs compare favourably with full mechanization of rock bolting in narrow stopes:

Capital cost
The capital cost of an Autorock drill rig (R20 000 – R30 000) is approximately 1% of the cost of a current mechanized rockbolter.

Operating cost
Operating cost (excluding labour) of an Autorock rig is approximately R2.00 per hole. The cost with a mechanized rockbolter is over R30 per hole.

Labour
The labour requirement is the same: typically two operators per crew, although both systems can be operated with one. However the operator of the fully mechanized rig must be more highly skilled and requires more training.

Output
Output of the fully mechanized rigs is usually less (Arthur & Taylor, 2004) due to the low maneuverability of the large equipment.

Ergonomics
Less physical work may be required for a well-designed fully mechansied rock bolter.

Safety
Safety is about the same for both – the operators spend approximately the same amount of time under unsupported hangingwall.

A compelling case can be made for mines not to single-mindedly pursue the full mechanization route but to consider Autorock drill rigs as an alternative. A similar situation exists in the UK, European and Australian coal mines, where hand-held roofbolters compete successfully with fully mechanized roofbolters.

Further developments

The mini-rigs have been adapted for use with the electric rock drills gaining acceptance on the SA platinum and gold mines. Where the electric drills are used, there is usually no compressed air supply, so the clamping and elevating cylinders are operated by service water. This has proven successful. Fully hydro-powered models have also been developed.

The main focus of future development is in the rock drill itself. To date, conventional pneumatic rock drills have been used with minor modifications. Increasing the torque and rotation speed of the rock drills will enable better spinning of resin-grouted bolts. Another problem with the current generation of rockdrills is their high noise level. This is being addressed in some prototypes currently under development.

Many gold mine stoping operations have similar conditions, constraints and requirements as narrow stopes in the platinum mines. The use of rock bolts for stope support has the same potential advantages as demonstrated in platinum and the several gold mines currently have mini-rigs on trial as part of a strategy of mechanization where justified.

Conclusion

With over 1500 units in service, Autorock rigs have proven themselves superior to conventional hand-held rock drills for installation of rock bolts in low stopes on the South African Platinum mines. The superiority comes from improved safety, higher productivity and better standard of rock bolt installation.

The performance of the Autorock rigs puts them on a par with fully mechanized low-stope rockbolters, but at a fraction of the capital and operating cost.

References

SA Dept of Minerals and Energy (DME)	Mineral Statistics Tables, 2007 (accessible from www.dme.gov.za)
Pickering, R.G.B.	Presidential Address to 110th Annual General Meeting of SAIMM, JSAIMM, 107 (9), September 2007

Arthur, J. and Taylor, J.	Status quo, opportunities and challenges of mechanized roof bolting, in Mechanised mining and support in the Bushveld Complex, SAIMM, 2004
Van Jaarsveld, G.	UG2 the Kroondal way, in Mechanised mining and support in the Bushveld Complex, SAIMM, 2004
da Costa, M. and van Vuuren, J	Improving stope support at Modikwa Platinum mine, 23rd Annual Conference on Ground Control in Mining, Morgantown, 2004.