LONG HOLE DRILLING AUTOMATION

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Summary

Sandvik Mining and Construction (SMC) have extensive experience of Drilling automation. The advantages of automation are many-fold. Normally the driving factors for increasing the automation level of the mining equipment are: higher productivity, cost saving, safety.

The current economic boom has increased tremendously the demand and prices of raw materials including metals and minerals. This has led into the situation where mines try to produce as much as possible to maximize their cash flow. The utilization and production capacities in drilling applications can be increased several ways by increasing the automation level of the machines. In almost in every case the operator safety is also increased due to the fact that operator spends less time in the potentially hazardous working area close the drilling machine.

The basis for the drilling automation is a scalable, decentralized control system. In Tamrock long hole rigs CAN-bus based control systems have been used since the beginning of the 1990's. More than 140 units with CAN-bus have been manufactured up to date. Current offerings include features like one hole automatics, up hole fan automation, data collection system, drill plan transfer and teleremote operation. Most of the long hole drilling rigs manufactured today are equipped with automation features. The advantage of the flexible operating system is the possible upgrade as retro fit packages of the automatic level of the machine to existing units.

Although the unmanned mine still remains a Utopia, a strong and unavoidable trend of drilling automation can be seen. More and more automatic features will be included in future drilling machines. However the implementation of automation has to be done in co-operation with the mines and machine manufacturer. The highly sophisticated automatic features also need special skills and readiness from various levels in the mine organization. Starting from operators and going all the way to the top management. For successful automation implementation there has to be full support from the whole organization. The potential benefits in drilling automation are so great that everybody should take serious considerations how to be able to utilize this potential.

Drilling automation Technology

The beginning of the long hole automation of Sandvik Tamrock drilling units goes back all the way to late 1980's. That time the first so called "Data" machine was launched. It was capable of drilling one hole by itself. However, from those days, huge development has been done in software, electric, hydraulic and mechanical sectors to improve the "intelligence" and reliability of the whole machine to get it into the level where it is at the moment. The first machines were equipped with control system having PLC electronics and
centralized hydraulic system. The limitations of these solutions were discovered soon and new type of control system was developed.

The basis for any kind of automated features is a suitable control system for a drilling machine. The control system comprises of two main subsystems: hydraulic and electrical systems. These could be also described as the muscles and nerve network of a machine. The hydraulic system contains all the valves, cylinders, rotation actuators etc. to realize to actual movements within the drilling machine. The electrical system controls the hydraulic valves and instrumentation.

The new electrical control system was realised with CAN technology. Additionally the hydraulic system was decentralized. The first long hole unit with the control system was launched in 1992. The main reasons for going into CAN were the following:-

**Modularity**
CAN nodes located around the rig to locations close to valves or sensors. They need only to be connected electrically in series with each other. By using additional decentralized hydraulics the number of hoses and cables can be significantly reduced, by up to 50%. This is a very relevant benefit for a drilling machine since most of the downtime comes from faulty hydraulic hoses or electric cables.

**Scalability**
New features or options can be readily added to an existing rig by just adding needed new components or subsystems and new software.

**Compatibility/Maintainability**
Product life cycle management is improved by device profiling - valves and transducers can be exchanged without (major) application modifications.

**Simplicity**
Intelligent actuators and transducers provide certain basic functions therefore those can be left out from application SW development project.

**Serviceability**
Intelligent actuators and transducers provide built-in condition monitoring and diagnostic functionality which improves serviceability of systems together with bidirectional communication interface to and from the rest of the system.

**Connectivity**
Onboard communication system provides information needed for upper level off-board information systems.
MAP project

Mine Automation Project (MAP) was a technology project between INCO mining company, Dyno Nitro Nobel, CanMet and Sandvik Tamrock. The project mission was to develop integrated systems of equipment and processes focused on reducing costs and exposure to potential hazards, maximizing manpower utilization and increasing quality and profitability. This technology will contribute to reducing overall underground costs per unit by a minimum of 25% of 1996 costs level and increase development advance rates by 30% of those obtained in 1996.

All machinery needed for the whole ore extraction process was used teleremotely to minimize the human entrance into the operation areas. However the practical limitation to this target was the trailing cable of drilling units. These units were powered with electro-hydraulic power packs and thus needed electricity for drilling operations. The tele-operated tramming was done from the service bay to the operating location, which was about 100m apart.

Sandvik Tamrock delivered one production drill, one development jumbo and one LHD that were automated for the tests. The long hole unit, equivalent to current SOLO 7-15F, was equipped with numerous automated features. The operation of the unit was done from a control room located at the surface. It was possible to tram and perform the drilling operations by using the teleremote controls. During tramming the operator had the video image all the time from the onboard camera system and in addition the information from the navigation system showing the
location of the rig in the schematic mine plan. The exact wall profile information was scanned with a separate surveying vehicle which was also operated by using teleremote control.

The operator had all the same drilling functions as with the on-board control panel. The operator could select the best view from four different cameras onboard. Audio was also available, as skilled operators can hear from the sound of the drilling if the drilling functions are set correctly.

The drilling plans from the mine data base to the control system of the drilling unit and upload of the real time data logging information was done wirelessly.

The onboard automatic features included an up hole fan automation. The rig was able to drill a fan automatically. Also a drill bit changer was fitted onboard. The bit changer could take up to 8 spare bits but it did not change the bits automatically. However the operator used it teleremotely.

These ambitious targets were to be tested and met during the final tests in 2000 at INCOs test mine, OB 175, in Sudbury Canada. Long hole production process tests included six successful cycles during which the performance and costs included were determined. One cycle consisted of:
- Teleremote tramming from service bay to production area
- Long hole drilling according to drill plan having only up holes, see Figure 2.
- Teleremote tramming back to service bay.
- Loading of the blast holes.
- Teleremote ignition of the blast.
- Teleremote mucking.

![Figure 2. Drill plan for MAP long hole production process](image-url)
Automation Features described

Automated features in long hole drilling are utilized in every day life in many mines today. More than 70% of long hole units delivered by Sandvik Tamrock are equipped with some automated feature. Below is a description of some of the current available products for CAN bus operated long hole rigs.

One hole automation
The rig is manually trammed into the drilling location. Operator sets up the rig and aligns the drilling feed into correct angles according to the drilling plan. Operator stabilizes the feed by driving the stingers into rock contact. After collaring the hole operator gives the planned hole depth to the system and activates the one hole automatics. The rig is then capable of finishing the hole automatically. It adds the rods into the string. After adding a rod the feed pressure is compensated for the weight of a rod. The actual feed pressure increase or decrease depends on the orientation of the hole and rod weight. As the preplanned hole depth is reached the string is given final rattling to shake the joint of the rods loose. This makes the uncoupling phase easier. It is easier and more gentle on the drilling machine to rattle the drill string against the bottom of the hole than later each joint separately at the front centralizer. Even the final rattling procedure has many alternative ways depending on the hole orientation, drilling tools (rods, tubes), break through hole or not. During uncoupling the program has to be able to manage lots of different special situations. It needs know how to open the thread when it is too tight. However the thread needs to be opened with minimum force or otherwise the service life of the tools will decrease. So the level of force will increase after every retry. It needs to know that correct end of the rod was opened. It needs to know the exact location of the rock drill and rod under uncoupling at the
time and so on. There are more than hundred of different internal registers which are used to tune the behavior of the automatic drilling. Some of them are accessible for the operators but most are behind a password and can only be changed by a system specialist.

The whole idea of automation is to mimic practices of the best drillers. The development of automated drilling program includes many man-years of programming work and endless discussions and advising from top drillers.

One hole automation program includes lots of features for special situations during drilling like:

- **Antijamming.** If the drill string start getting stuck the rotation pressure will start to rise. If a limit value is exceeded then the feed direction is changed into reverse and percussion is limited to half power. Restart of drilling is carried out cautiously with half percussion and slow feed.

- **Break through.** Sometimes the holes are drilled through deliberately to adjacent stope or open level above. However the exact length of the hole is not necessarily known. For this kind of situation the program includes feature called break through. The hole length and a tolerance value is given by the operator. If the hole length is 20m and the tolerance is 2m then the program starts to monitor the penetration speed after 18m. If the break through speed is exceeded then the hole is regarded as finished and normal hole end procedure can start.

- **Rushing.** There is a separate setting for situation when penetration resistance suddenly drops. This is the case when drilling into cavity or weak zone. If the preset penetration rate is exceeded the feed direction is changed for a moment. Retry is carried out with half percussion and cautious feed. This is very important to prevent the rod from bending and resulting deviation of the hole.

### Up hole fan automation

In addition to the one hole automation up hole fan automation feature makes it possible to drill several holes automatically without operator interference. For this purpose the rig needs to be given the drilling plan. In the plan every hole is given a sequence number, hole depth, tilt, rotation and off-set values. The off-set value defines the pivot point location in relation to the navigation point. The number of the pivot points is not restricted.

Operator manually drives the rig to the fan location and sets up the rig. This is done by aligning the side lasers to the wall marks painted by the surveyors. After that the rig control system has to know the center position of the drill plan. Operator manually moves the boom to the centre point of the drill plan. This is normally also the drift centre line and a separate line is painted on the roof to mark it. As the drill bit points vertically up and aligns with the centre line the navigation position is accepted by the operator.

After launching the automatic mode the rig automatically positions the boom and the feed to the correct values given in the drill plan. The rear and front stingers are driven to the rock contact. Their pressure is monitored and maintained throughout the whole time of the drilling. This ensures good stability for the collaring, drilling and uncoupling. This is very important for the quality of the hole. The more stable the feed is, especially during collaring, the less the deviation that occurs.
An additional benefit with fan automation is the hole quality. With automatic aligning of the hole the accuracy is not function of the operator skills level nor his motivation. The collaring will be done always within the tolerances which are parameters in the system.

The possibility of machine damage due to improper usage also decreases, because the operator needs to do less manual intervention. The automatic functions will always be done in a predefined manner for movement speeds and paths.

In LKAB Kiruna mine there are three Sandvik Tamrock long hole rigs equipped with up hole fan automation feature. This is used extensively with these units. Close to 90% of the total meters are drilled with it. In Kiruna mine there are three shifts but only two of them are manned. The night shift, between 23.00h and 06.00h, the rigs is left to drill by themselves even without teleremote supervision by the operators. On average 80 drill meters are achieved during the night shift which equals about 25% of the total drill meters.

Teleremote operation
Teleremote operation provides the possibility to have the operator in a different location from the drilling unit. The drilling control panel has identical functions as the local panel on board. Cameras attached to the pan/tilt head can also be operated from the operation location for best possible viewing angles. Audio system compliments the camera views to give a more realistic and informative scene of the drilling.

In theory there is no limitation to the maximum distance between the operator and the rig. In practice the data communication bandwidth and its latency may become restricting factors. For good quality video picture 1 Mbps is needed. The overall latency for controlling machine teleremotely should not exceed 200-300 msec. If the delay is greater then the feedback of a control command (to see the movement in the monitor) is too slow.

The operator station may be located either in a movable container fairly close to the rigs for example as in the top hammer rigs in LKAB Kiruna mine, Sweden, see Figure and Figure.
Alternatively the operator station is stationary, located underground or at surface. For example, INCO Stobie mine, Canada operates the rigs from surface.

The biggest advantages of teleremote drilling are:

**Safety,**
The operator spends less time in a potentially hazardous drilling area. In some cases mine regulations even prohibits on board operation for example, when drilling in an area with possible misfires.
Operator exposure to the dust, exhaust fumes, heat/cold and vibrations can be also prevented. **Productivity,** the productive hours of a drilling unit can be increased. Usually a substantial amount of shift hours are used travelling from the change room to the drilling unit. With teleremote drilling it is possible to have a "hot seat" changes.

**Ergonomics,** Operators can be located in better working conditions and thus increase their motivation. Additionally seemingly small issues like neck and shoulder problems can be avoided since the monitor at operator location is ergonomically positioned. In stead of turning their head up to see the up holes or down for down holes the operator needs only to adjust the camera.

In both of the mentioned example mines one operator is taking care of multiple rigs. However, with a surface based control station somebody is needed underground to give the daily service and change the bits and move the rig to new fan location after finishing the previous drilling shift.

**Near future Development**
Sandvik Tamrock and LKAB have signed an agreement to develop a new generation long hole fleet using Wassara technology for LKAB's Kiruna and Malmberget mines. The agreement does not only include the drilling rigs but also operation and management systems to combine the units into the existing production process with links to the mine design and quality verification systems. There will be one central operation control room for each mine to teleremotely operate the fleet in that mine, see fig 6. The rigs will be equipped with up-hole fan automation, automated hammer changer, Teleremote control system and Real Time data acquisition system.

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**Figure 6. LKAB long hole machine fleet management architecture**
The South African Institute of Mining and Metallurgy

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The contract includes minimum of 10 drilling units and two fully equipped central operation control rooms. The delivery of the first unit is scheduled to be at the beginning of 2007.

Implementing Automation
Successful implementation of any level of automation features is a close cooperation process between the customer and SMC. It is highly important that all levels of the customer’s organization are involved in this. The entire production chain and process needs to be clearly defined and requirements for every phase have to be included in the automation plans and in the realization of these plans. This covers all the necessary functions and supporting systems used for extracting the ore from in situ situation to hoisting and further processing.

Operator involvement from an early stage can not be over emphasized. The natural behavior of humans is to reject any changes that makes one’s future insecure. Normally one factor in automation is the decreased need of labour type work. How does one get operators accept the coming change? Even the type of payment may make a difference to the success for implementation. In most of the mines today some kind of bonus system is used. The operators are paid according to the meters they produce individually. This translates easily into maximization of personal income without thinking of long-term optimization. To get the maximum number of meters during one shift may lead into situation where the daily service actions are sacrificed and availability of a drilling unit is decreased.

The best overall result can be achieved by combining well planned services with motivated operators. The operator motivation must become from the performance of the whole group not individual results. Using machines too harshly to maximise the operators’ personal meters drilled will not achieve overall optimal output of the drilling machines.

Conclusion
When a drilling unit is working without human supervision in automated mode it must be mechanically and electrically reliable. Additionally the control system program has to be intelligent enough to clear special situations of long hole drilling e.g. stuck rods, break through situation and rushing. Also sometimes the joints of the string may be hard to open or they tend to open from wrong end. During manual drilling these kind of special situation may not even be noticed by the operator since he can carry out the corrective action immediately. Even small repairs of the unit may be done during the drilling without losing any production. In case of automated drilling unit even small malfunction may stop the drilling until the operator takes over the command. The lost production may be in worst cases almost the whole shift. This is the case for example when drilling with automation over unmanned shifts.