THE AGE OF INTELLIGENCE. ONLINE DIAGNOSTIC AND AUTOMATED MAINTENANCE PLANNING

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Abstract

Reduced downtime and maximized availability of mining machines are the key factors in optimizing production rates. As technology moves industry towards an age of 'intelligent machines' it sets the foundation for change in mining equipment design, functionality, and maintenance. Recent mining machine designs are integrating more and more electronic components into the core functionality of individual piece of equipment due to regulatory and legislative requirements, such as TIER rating, as well as from a safety aspect such as personal detection systems.

This paper describes the use of existing on-board electronic equipment to increase machine availability through automated maintenance planning and diagnostic fault-finding capability. The automated maintenance planning takes place on the machine itself in order to be independent of the mine's infrastructure, while the diagnostic capabilities allow for reduced downtime.

The paper also presents a concept to transfer operational data to surface to be able to optimize planning of maintenance and to reduce downtime.

Case studies are presented where such systems have been commissioned and are currently in operation, the possibilities of this technology application for the future are examined.

Introduction

Over the past 20 years underground mining operations have started to focus on data-capturing and 'black box' technologies, but the full achievable advantages, not only from a productivity point of view, but more importantly with regards to significantly increased production and reduced downtime, are not yet understood or realized.

The current and future challenges around optimizing mining operations, as well as the lack of real-time information to monitor and improve performance, has led to the need to capture data as a platform for further analysis to better understanding shortfalls and areas for improvement in the operations.

Sandvik products are recognized as some of the most safe, reliable, and productive pieces of mining equipment in the global mining industry, with customers world-wide relying on our equipment to achieve production targets. From its inception in 1862, Sandvik has seen significant challenges and demands from the mining industry leading to the need for continuous innovative technology solutions. The ever-increasing focus on greater production and profitability, reduction of costs, and ultimate optimization of mining operations has led to the need to continuously improve understanding of the shortfalls and constraints in the entire mining process. In order to better understand the health and performance of equipment, it imperative for operational improvement to be realized.

A look at medium- and long-term trends in underground mining enables us to begin to grasp the significance of real-time operational information as a key success factor of underground mining in the future.

With the aim of staying on the forefront of technology advances, Sandvik has been developing and growing its 'data-capturing and management and automation' offering for over the last fifteen years. Sandvik has accumulated a long history and experience in mining equipment. Since the late 1980s Sandvik has participated in various research and development programmes together with many other mining companies, leading to the start of development of an integrated system for semi-automated loading in 1999, with the Sandvik Tampere test mine being established in 1999. Development work was later conducted to expand the capabilities of the system for automated hauling during 2001. The first phase of the system was completed in June 2004 in South America at Codelco's El Teniente Mine. Similar systems are operational in North and South America, Africa, Australia, and in Europe. More recently, in 2007, Sandvik started the development of a system known as 'Instandhaltungsplaner,' (Maintenance Planner) which was implemented and commissioned in 2009.

Current technologies

The most important factor influencing a machine's performance is its availability.

In order to obtain optimized utilisation and a long lifespan of equipment, maintenance is a necessary evil, which causes the mining equipment to be out of production and therefore reducing the availability.

Over the past couple of years different strategies have been implemented by different mining houses to optimize maintenance cycles. Most of these strategies implemented time-based schedules that depend on machine running hours irrespective of the actual conditions the machines are working in.

With the introduction of electronic components such as engine management systems and on-board control and diagnostic systems on underground mining machines, the potential to optimize the maintenance cycle and increase machine's availability has increased significantly.

In order to test and validate the concepts of remote ’real-time machine data capturing’ and self-determining, self-regulating functionality, Sandvik put an Intelligent Roadheader, ITSM® AM105, into operation in 2009 at a German mine called Prosper – Haniel as part of the Deutsche Ruhrkohle mining house (Figure 1). Although the concept was tested in a coal mine, the technology can easily be adopted to function in any hard-rock mining applications.

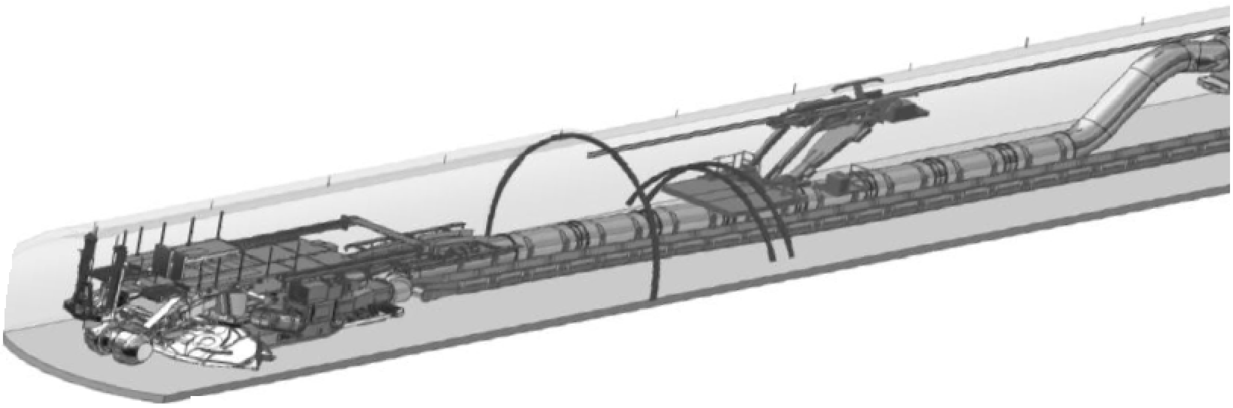

Figure 1- ITSM AM105 with onboard bolting and scrubber system

The remaining part of this section walks us through this machine‘s fundamental datalogging functionality as well as its interface with not only the mine’s software infrastructure and databases, but also the interface with procurement and maintenance divisions.

In order to achieve condition-based maintenance, all relevant machine parameters are monitored by the machines on-board sensors. The machines’ on-board control system then processes the incoming data and compares it with the machine manufacturers’ database to ascertain whether these values are within the defined parameters or if maintenance needs to be scheduled within a set period of time.

Out of this data, maintenance dates are scheduled and optimized related to the actual load on the machine. Routine machine hourly-based maintenance can be avoided and the time involved minimized, thus reducing downtime and improve availability.

Before maintenance starts, the machine informs the crew about possible special tools needed to carry out the respective task as well about consumables needed. This not only reduces the level of service skills required, but also minimizes the time the machine is not available for the mining operation, as tools and consumables can be pre-organized and made available. With the ever-dwindling skills availability and the constant drive to reduce downtime and costs while increase the efficiency of services, these 'intelligent' machines can only support this philosophy in the mining industry.

The system has a defined interface to SAP, a maintenance planning system, which has been tested and successfully implemented in a German mine. The benefits of this integration are:

- Direct connection to purchasing

    The machine itself 'places an order' for the consumables needed for the next maintenance. An automated system makes sure that all parts and consumables are available when the next maintenance takes place and therefore minimizes the possibilities of excess downtime or skipped maintenance due to unavailable parts or tools.

- Mine interaction

    The SAP interface enables the mine to combine and analyse their own productivity data together with the machine's performance data.
    As not all machine conditions can be monitored directly by on-board sensors, various sensor signals can be combined logically to get a better understanding of the machine's performance and constraints.

- 'Maintenance planner' machine integration (Figure 2)

    Although this maintenance planning system is directly integrated into the machine's core functionality, it remains a stand-alone system that can be easily removed or added to the machine. It does not interfere with any safety or routine functionality and purely provides a form of independent 'health' monitoring, diagnostic capabilities, and maintenance scheduling.

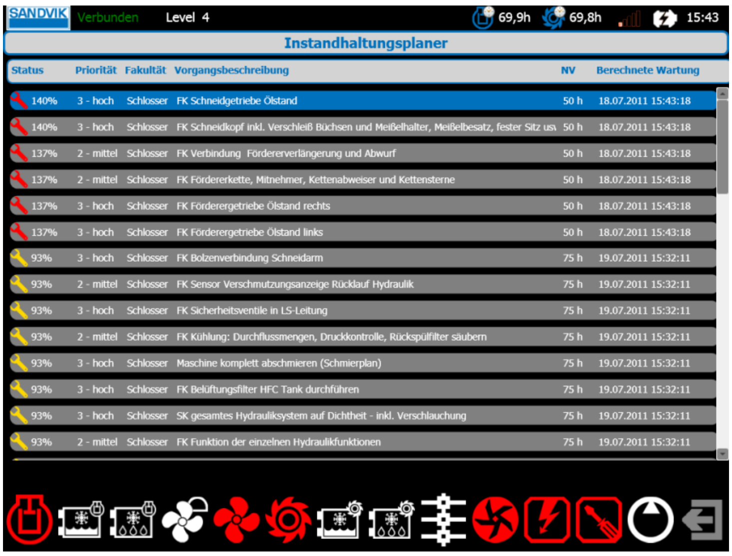

Figure 2-Interface of the maintenance planner

The main goal in developing an automated diagnostic system is to determine the actual status of the machine and to recognize different functional errors.

The system has to be capable of detecting and analysing error conditions, classifying them, and determining the possible cause. To achieve this, the various existing on-board sensors are interlinked, and together with the status the machine had been in when the error occurred, the condition is evaluated.

The development of the on-board diagnostic system is divided into three phases:

- The first phase deals with gathering all relevant machine information and storing it in a predefined database. This historical data is statistically evaluated and categorized according to its severity and abundance.

- Phase two involves adding advanced data evaluation, including a plausibility check, to the data collected in phase one.

- Phase three completes the on-board diagnostic system with a monitoring module supervising the data communication to off-board third-party systems such as SAP or SCADA packages.

During the trial period of the AM105, milestones were set after each of the phases listed above, and successful completion of each phase was required before moving onto the next phase. After successful completion of all the phases, in conjunction with the achievement of the initial defined KPIs[1], the technology project was deemed successful. In a drive towards continuous improvement, and due to customers' ever -hanging needs and the requirements of the mining industry, software upgrades are continuously being implemented in order to achieve an optimized remote interface.

Data transfer

Although the machine's data logging and performance monitoring capabilities have proven reliable, the main challenge remains in downloading the collected data from the machine and making it available in a control room for further processing. With an electrically powered machine, the trailing cable can be used as a transport medium to transfer data to a defined point. Inductive coupling is the safest and easiest way of using the power line as a transport medium. The needed equipment couples inductively to the phase, which makes high-voltage barriers obsolete. Although having some shortcomings such as sensitivity against core saturation, this kind of coupling has proved itself in various mining applications.

This type of data transfer has the capability to transfer data from the machine back to the substation, where it can be easily picked up and transferred further on using one of many different types of transfer mechanisms such as WLAN, fibre optic network, or simple two-wire data transfer.

In the surface control room, the data is stored in a SQL database and can be used for further post-processing and machine visualization (Figure 3).

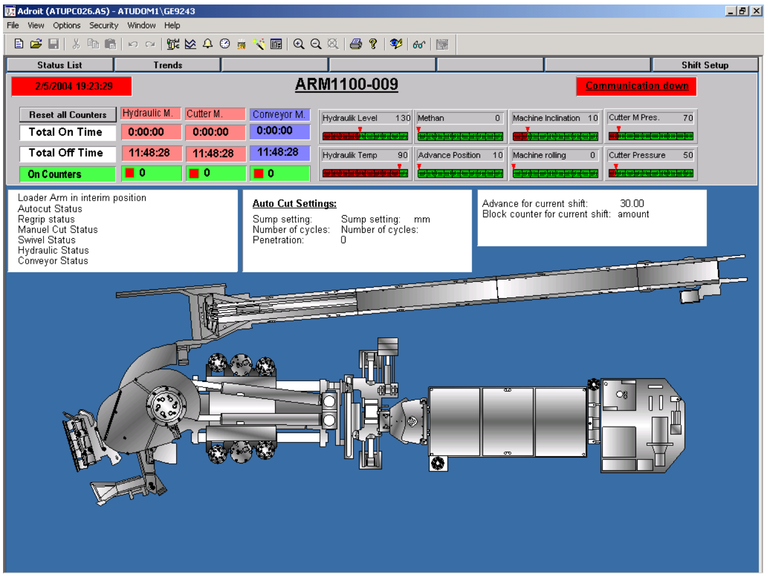

Figure 3-Online machine visualization

Benefits and challenges

As the mining industry moves towards an 'age of intelligence' with a continuously increasing need for real-time data capturing and performance monitoring, original equipment manufacturers are driven to stay at the forefront of technology advancements, providing benefits as listed below.

Benefits

Improved fault-finding capabilities and root cause analysis – after a problem has occurred, the downtime required to fault find can be extensive and expensive on-site diagnostic tooling is often needed, before it is rectified

- Enables move from reactive to proactive maintenance
- Optimizes use of workforce and minimizes travel
- Technical support technicians can remotely access the real-time performance data for technical assistance and fault-finding. This information may then allow certain components to be replaced before they fail, saving downtime and reducing lost production and parts costs

- Capturing of operational data (Figure 4) allows for analysis and optimization of the mining process
- Real-time condition monitoring
- Reduces. unplanned downtime
- Improved product development process for next generation of equipment
- Storing and analysing data allows operators to become proactive and apply best-practice monitoring techniques.

The main challenge remains in the evaluation of the gathered information. Relevant data for the respective task has to be extracted and separated from irrelevant information and needs to be interlinked with other sensor data and the current machine status.

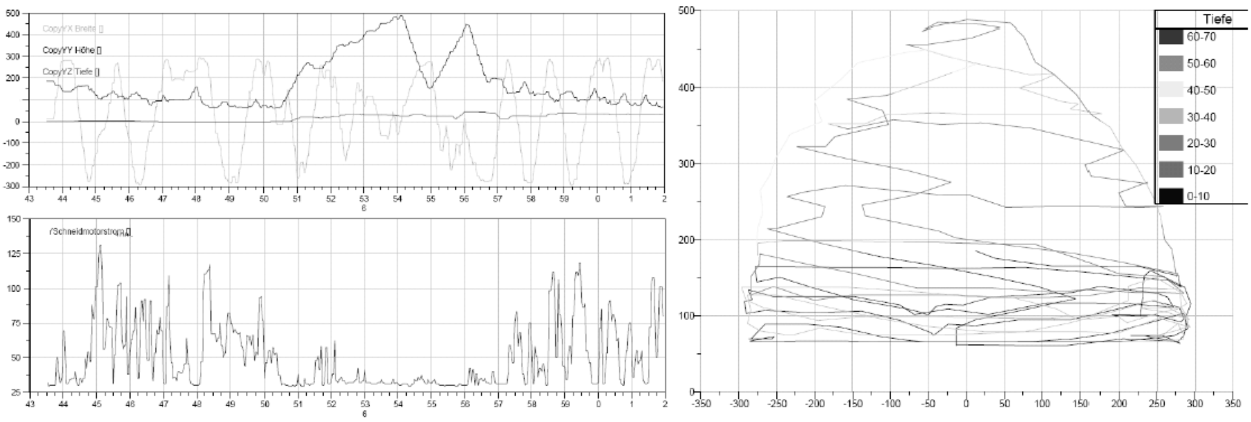

Figure 4-Example of a cutting path evaluation from historical data

This is where a mine’s operational expertise and machine design knowledge together build the basis of a successful maintenance planning tool that helps reduce machine downtime and even provides a safer working environment through minimizing unpredictable machine conditions.

The fact remains that from a data-capturing perspective just about everything on and around mining equipment can be captured, but it is the next step, of successfully analysing the data and inputting it back into operations to optimize them and add significant value, that remains the greatest challenge of all.

Future

The integrity of machine data remains one of the main challenges in today's data collection and evaluation processes. The main differentiator between mining and plant installations is the moving working place in mining as the face advances. It is therefore difficult to install and maintain reliable networks and infrastructure, and makes on-board diagnostics an absolute must, to ensure a high availability a safe and uninterrupted operation of the mining machinery.

Although the mining industry, and the end-users in general, are trending towards requiring more data-capturing capabilities in their mining operations, it still remains a challenge for OEMs and end-users to jointly find consensus as to what information is most beneficial and adds the most value with regards to optimizing an operation. It is one thing to be able to capture and store data, but something else entirely to be able to compile reports that add value and can ultimately be effectively utilized.

In a continuous drive towards improved mining cycles through optimized machine utilization, Sandvik is developing machine concepts together with end-users that not only provide reliable machinery, but also support the user in utilizing and maintaining the equipment in the most effective way.

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Alfred is a qualified Automation Engineer and joined Sandvik in 1998. During his time at Sandvik Alfred has participated in Product Development on a factory level, through various roles such as Senior Designer Software & Automation, Automation and Instrumentation Manager, Technical Manager and Manager Automation, Offering Development. Alfred has also qualified as an International Mining Engineer through SIMS, a global mining degree offered through Sandvik, giving him a well rounded approach to both the technical and operational side of mining. Alfred has had both back-line and front-line experience, working with Sandvik's Product Development Centres and the Regional Sandvik teams on new product development, implementation and support in the field, as well as working with Business Development on growth in the market.