THE EVER-INCREASING ROLE OF AUTOMATION IN DEVELOPING THE "INTELLIGENT MILL" OF THE FUTURE*

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Abstract
The Danieli Group is deeply involved in the technological improvements stimulated by Industry 4.0 concepts widely applied to the metals industry and process automation. The so-called "Intelligent Mill" is the natural evolution of the company's consolidated know-how and undisputed leadership in the fields of mini-mill and turnkey plants. Complete and structured data collection is the basis for real-time analysis and process optimization in terms of quality, efficiency and easy maintenance. A centralized repository of information is possible thanks to the strong interconnection between process control system architecture and intelligent sensors, together with dedicated software tools leading to an intuitive approach to data analytics.
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1 INTRODUCTION

Several integrated packages make up the process automation architecture of the "Intelligent Mill", with the main following functions:
> Production scheduling (Production programming, plant stoppage tracking, shift and personnel management)
> Tracking of products (Continuous product tracking from continuous caster to storage area)
> Tracking of quality (Real-time monitoring of product quality during all process stages)
> Tracking of tools (Mill dress and Workshop management)
> Modeling (Dimensional control of finished product by real-time model of rolling process)
> Energy monitoring (Consumption measurement for a real estimation of running costs, with the possibility to act on process equipment and auxiliary plants to reduce production costs)
> Maintenance management (monitoring of working hours of main components, condition monitoring systems with predictive maintenance features)

The above are a consolidated set of functions needed to produce quality materials efficiently. The innovative part of the intelligent mill proposed by Danieli Automation is how tracking, data collection and analysis are performed.
Acquiring field signals and process condition information is the first step: this is about sensors already installed in the past but whose use was limited. The technological breakthrough is the centralized acquisition of these signals in order to monitor the working conditions of our products and to further understand the correlations in terms of cause/effect. Thanks to collected and properly organized data, it is possible to build models which correlate past failures with the variables observed at the same time. Consequently, the models fed with real-time data from the plants can make predictions. The results of these predictions are then sent to the automation control system of the plant to perform prescriptive maintenance and let the machines automatically react under certain conditions.

2 INTELLIGENT SENSORS

The small, robust HiSection sensor monitors and tracks the product section along the mill. The proper feeder is always guaranteed at sizing stand entry side, while the finished product dimensions and surface defects are measured / identified by the HiProfile sensor.
HiSection is a family of magnetic sensors for non-contact on-line measurement of the cross-sectional area and weight per meter of hot-rolled bars. These sensors can measure round, oval and rebar profiles.
The system is ideal for any application where bar section and/or weight per meter must be continuously monitored in real time.

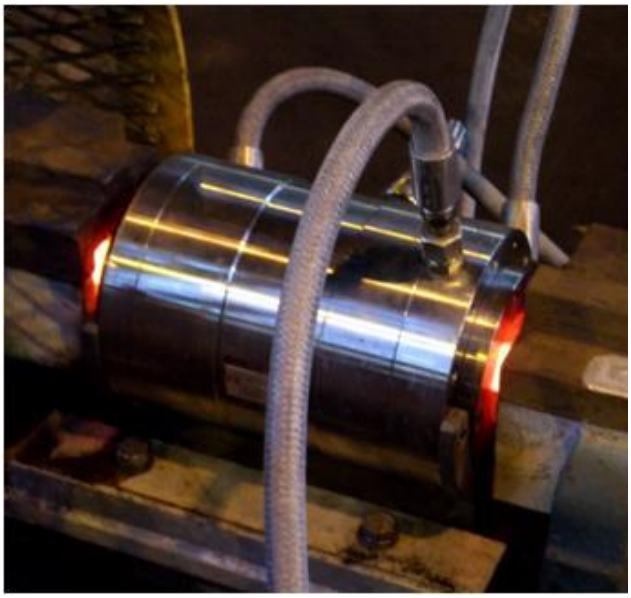

Figure 1. HiSECTION - non-contact eddy current system for in-line measurement of cross sectional area of hot-rolled bars.

The system uses an excitation coil to induce a pattern of eddy currents on the surface of the rolled bar. The eddy currents produce a return variable electromagnetic flux which is detected and converted into electrical signals by a dedicated pick-up coil built into the sensor itself. The reactance value of the electromagnetic circuit generated in the sensor as the bar passes through it, is continuously monitored. An alarm is immediately given if the rolled product is out of tolerance.

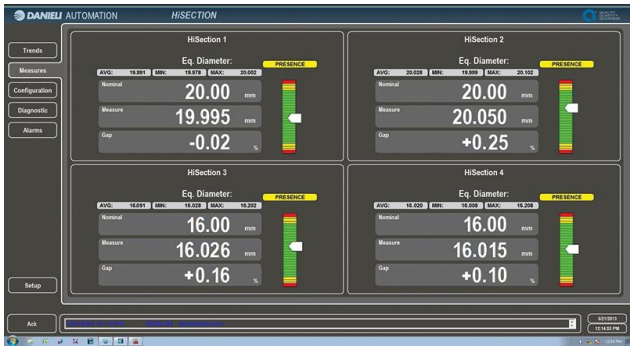

Figure 2. HiSECTION - HMI workstation interface.

The immediate benefits of the sensor are more stable rolling conditions, which lead to a drastic reduction of breakdowns in the roller guides, extended life of the rolls and absence of cobbles.

Figure 3. HiPROFILE - Laser profile gauge for hot & cold long products.

HiProfile is a well-known laser measuring device for profile shape inspection and dimensional measurement of hot and cold-rolled sections, directly on the production line, without physical contact.
Thanks to the very short exposure time, the entire cross-sectional contour of the bar is captured in less than 20 micro seconds, guaranteeing complete immunity to bar vibrations.
The short exposure time allows the system to acquire such a clear image of the rolled product that it can even clearly detect the presence of defects on the product surface.

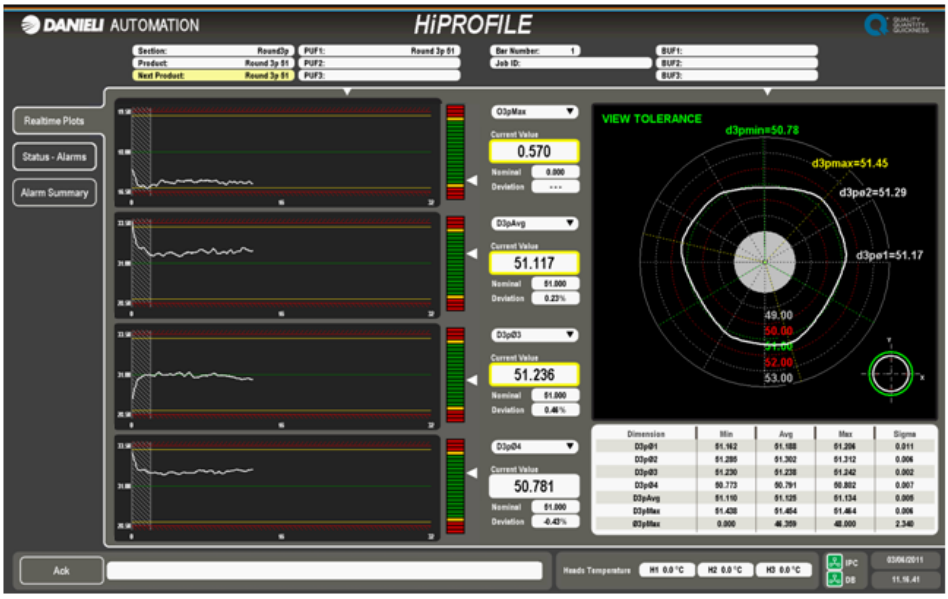

Figure 4. HiPROFILE LITE - User-friendly HMI interface.

The immediate benefits of the device are quality control of profile shape and surface through capture and measurement of the entire bar profile, which guarantees an immediate on-line feedback of the final product (absence of dimensional and surface defects).

3 TRACKING OF TOOLS

Another key function which characterizes the “Intelligent Mill” is the tool tracking function (Mill dress and Workshop management). This function is based on the use of RFID tags installed on all rolls, cartridges and guides of continuous rolling mill and sizing stands, for easy, fast and error-free assembly of cartridges, proper on-line mounting of stands and roll machining by operators.

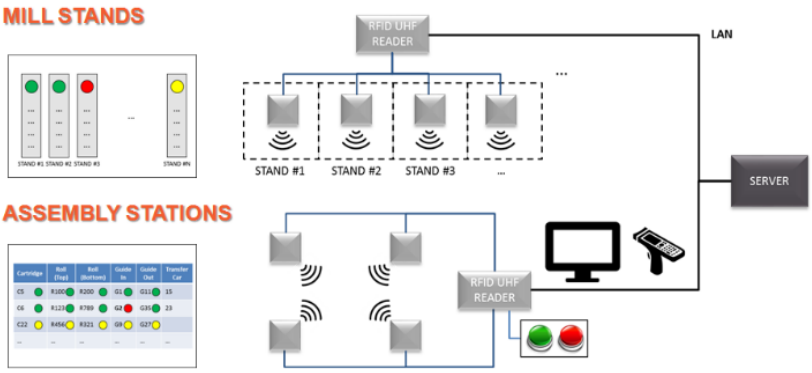

Figure 5. Tool Tracking function working scheme.

The RFID application guarantees:

> The correct assembly of the desired cartridge on the rolling line and consequently the rolling set-up
> The correct mounting of all desired components in the workshop
> The correct parameter set-up for the lathes, according to the cylinders to be mounted
> The proper management of the component warehouse, keeping data updated

The “Intelligent Mill” also provides an innovative interface between the process control system and the lathes, for automatic machine set-up according to the mounted cylinder ID and its groove shape data. Moreover, at the end of the redressing process, the system is able to record and save in the database the real redressing depth, beginning and end hour and data of the activity, identification of the lathe and operator name.

4 CONDITION MONITORING SYSTEM

For efficient maintenance management, Danieli has developed its own Condition Monitoring System (called Q3-CMS), which is a predictive maintenance tool that uses one or more parameters to monitor the equipment’s operating condition, where any significant variation in signals could be indicative of oncoming damage. This makes it possible to take the appropriate decisions in advance to schedule maintenance activities.
Danieli Q3-CMS is a flexible, modular application, and combined with high-quality service assists the customer in monitoring equipment status during operation. It is typically made up of a specific number of sensors installed in strategic positions on the machines, with dedicated hardware and a server workstation that guarantee online control and visualization of the vibration and temperature amplitude levels, tracking the historical data trends. The vibration signal, together with other signals, makes it possible to understand the real status of the machine.
The signals that can be monitored by Q3-CMS are:

> Vibration,
> Bearing temperature,
> Oil contamination particles, temperature and water saturation,
> Spindle torque.

Danieli Q3-CMS is totally integrated with the plant automation platform to synchronize data acquired by the sensors with process information for a complete

scenario of equipment conditions. Monitoring machine status during operating mode and recording the vibration and temperature data provides a full analysis that shows the situation for each rotating equipment component, making it possible to identify fault symptoms at an early stage and giving valuable information for corrective actions to be scheduled during the planned maintenance.
In fact, the Q3-CMS can be fully integrated into the Danieli Maintenance Management System (DMMS), which is a comprehensive package linked to a process control system for maintenance planning, cost and performance controlling, equipment history and inventory handling.

5 MAINTENANCE MANAGEMENT SYSTEM

The Q3-DMMS is a computerized maintenance management system, specifically designed for the metals industry to control the preventive maintenance activities (routine and daily maintenance), as well as emergency maintenance, spare parts management, specialist scheduling, outsourcing, planning, equipment costs and fault analysis.
The system can be interfaced with MES (Manufacturing Execution System) for sharing of the plant production calendar, and with the process control system for synchronization of key equipment data (i.e. worked hours, number of cuts, tons produced, cycles, etc.) with the management of maintenance work orders, giving the planners an overview of the activities that need to be done within a given timeframe. This system can also be interfaced with the Customer's ERP.

Customized reports are prepared in strict cooperation with the maintenance manager during the on-site tuning of the DMMS, in order to generate documents containing the most suitable and useful information for personalized maintenance management, like analysis of hours worked by the equipment, mean time between failures, scheduled/unscheduled stoppages, team performance, consumption of spare parts and consumables, costs, equipment fault analysis, analysis of suppliers, component lifetime, forecasting of spare parts consumption, forecasting of "mean time between failures".

The database also contains Bills of Materials, spare parts lists, drawings, data sheets, maintenance manuals and catalogues that refer to the equipment of both Danieli and its sub-suppliers.
The main benefits of the Q3-CMS and Q3-DMMS systems are:
> Higher machinery reliability,
> Increased productivity due to higher equipment availability (reduction of production stoppages),
> Elimination of unplanned failures,
> Improved overall equipment efficiency,
> Reduced maintenance and personnel costs by knowing the exact problem to fix,
> Optimized management of spare parts,
> On-line drawings, instructions and documentation.

6 DATA-DRIVEN METHODOLOGY

Danieli Automation is implementing innovative technical decisions based on "Data Driven" methodology, which consists of an integration process between mathematical

models and statistical instruments and analysis for continuous improvement and assistance in decision-making.
The characteristics of this “Data Driven” methodology are:

> Unified data models that collect the multiple sources of heterogeneous data in a centralized repository,
> Integration of advanced statistical engines for deep data mining,
> A front end that can be immediately understood and used.

The core of the Data Driven solutions is a product developed by Danieli Automation called Q3-Intelligence, which is the advanced business intelligence system devised and engineered for the Metals Industry. The platform includes sophisticated components and industry-specific analyses that are helpful for decision-making and to increase the value of users’ businesses.
The features of the system are:

> Data Warehousing and Presentation to support Decision-Making (thanks to innovative real-time dashboard presentations giving quick, easy access to process data and KPIs),
> Data Mining techniques to transform data into knowledge to support business (i.e. multi-dimensional data models to easily correlate different data).

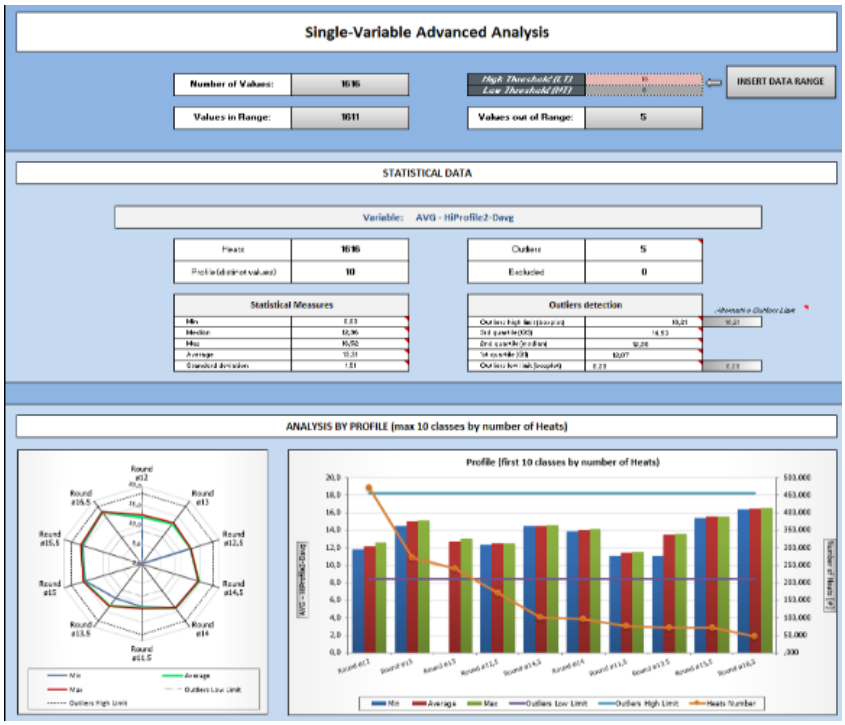

Figure 6. Q3-Intelligence: advanced business intelligence system for the metals industry.

Gathering and transforming data from sensors and systems is essential to vastly improve operations and results in the metals industry, in detail:
For product quality analysis on sections, the dimensions and defect-related data collected during the different campaigns and the feedback from roll wear measurement make it possible to adjust the model applied for wear recovery on roughing and finishing stands.
The “Intelligent Mill” is characterized by a single pass up to the sizing end; therefore, the stands before the sizing mill work until the end of roll life, and wear recovery is mandatory to ensure that the finishing stand receives the proper feedstock.

The correlation between the huge amount of data coming from the laboratory, HiProfile detected defects, process (i.e. temperature, heating and cooling patterns, rolling torques, etc.) campaign by campaign, leads to a continuous improvement in product quality thanks to data-driven set-up/adjustment of the “Intelligent Mill”.
In the Workshop, after each redressing activity, the wear of the rolls and the information pertaining to the machining itself are stored in the database of the “Intelligent Mill” in order to analyze the operating life of the rolls: the data on roll wear are correlated to the production data (hours and type of production) to achieve a statistical analysis of roll consumption. This leads to a prediction of roll life-time and the possibility to send an alarm to operator interfaces when the rolls mounted on the machine need to be replaced.
Finally, by correlating data coming from the Danieli Q3-CMS and Q3-DMMS systems and production, the “Intelligent Mill” can predict faults at an earlier stage and validate the strategies applied during ordinary maintenance.

7 CONCLUSIONS

The systems described above are capable of tracking production and machines, keeping quality under control and helping to improve it, managing energy consumption, assisting maintenance and enhancing process control for the mill.
Summarizing, collection and the centralized repository of field signals and process data, together with powerful tools to analyze them to provide performance indicators, predict system behavior and improve process control represent a new frontier for the “Intelligent Mill”.