Production Quality Secured by New Real-Time Plant Condition KPI Approach at Big River Steel CSP

Digital technologies are transforming industry at all levels. Steel has the opportunity to lead all heavy industries as an early adopter of specific digital technologies to improve our sustainability and competitiveness. This column is part of AIST's strategy to become the epicenter for steel's digital transformation, by providing a variety of platforms to showcase and disseminate Industry 4.0 knowledge specific for steel manufacturing, from big-picture concepts to specific processes.




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Big River Steel (BRS), located in Osceola, Ark., USA, on approximately 1,300 acres (5 km^2), is one of the country's most modern and environment-friendly steel works. Applying innovative, clean and effective processes, the company produces high-quality steels for the energy, automotive, and oil and gas industries from mainly recycled steel scrap.

The plant has an annual capacity of 1.5 million metric tons of high-grade steel products and special steels.

The capacity of the plant will be increased further up to 3.0 million metric tons in a second construction phase, which started in January 2019.

As a provider of integrated systems, SMS group supplied all units — from the melting plant to the finished steel strip, including all drive and hydraulic components, the entire electrical equipment, the complex automation systems as well as the environmental technologies.

Big River Steel's Learning Steel Mill

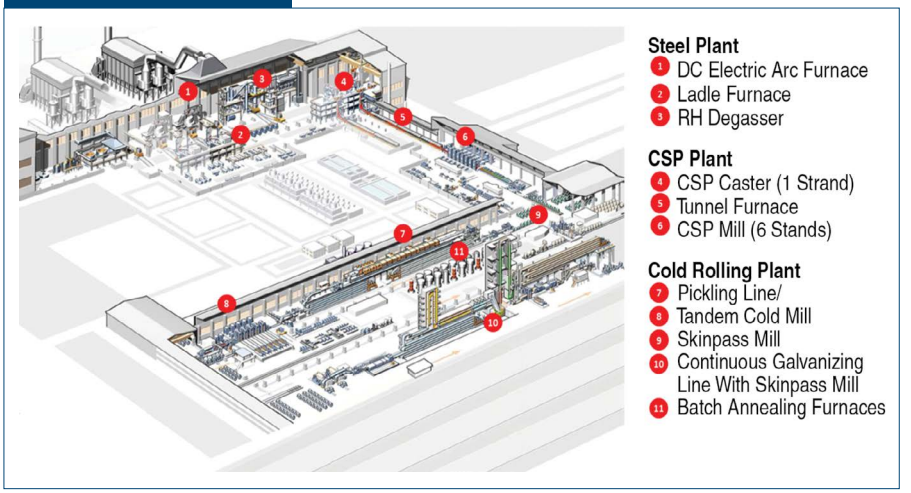
— The primary work in a steelmaking plant is performed by production and processing systems. Such systems produce a large amount of data. Their data are of interest for various types of performance evaluation and adaption systems.

Here two quotes from Big River Steel about their objective — the learning steel mill:

"Think of the hundreds of thousands of sensors, scanners and detectors that our Flex Mill™ equipment uses every day as we turn scrap metal into new, niche steel grades. All the data from that equipment is being read, measured and reported every step of the way. Now imagine harvesting that data, and the immense amount of knowledge and insights it contains. Imagine using that information to make those quality steel products in smarter, faster, and more precise ways. That's the power of artificial intelligence (AI)."

"We created a learning mill that is integrated at a level that was previously thought impossible."

Figure 1



Overview Big River Steel mini-mill complex.

In a learning steel mill, various data are used to evaluate points that are of prime interest to the operating company and its customers. Two of the most important points of these evaluations are product quality and production condition, along with predictive maintenance.

Equipment Performance Along With Product Quality — Besides the production planning, the production and process conditions are essential factors, influencing product quality and plant performance. Poor production conditions cause worse product quality results. So when evaluating products and searching for reasons for declined quality, it is essential to focus on the production conditions, too. Being able to make predictive evidence about the equipment-related production condition within the near and very near future allows planning predictive maintenance activities and possibly rescheduling of production planning, if the process conditions aggravate dramatically.

SMS group's contribution as a complete system supplier is to provide equipment-related information regarding production conditions that are comprehensible, visible and perceptible for maintenance and operation personnel.

Discussion

In order to reach the goal, i.e., to identify relations between plant status and resulting product quality, to give an early recognition of problems that probably will occur if continuing and to allow taking measures to avoid those problems, the following steps have been made so far.

In the first approach, a Product Quality Analyzer (PQA®) has been deployed at Big River Steel taking into account the entire process chain from steelmaking to the final product. The PQA system is well established and operational for almost all parts of the Big River Steel plant.

As an essential basic functionality, a Production Data Warehouse (PDW) has been established as long-term storage of all required data.

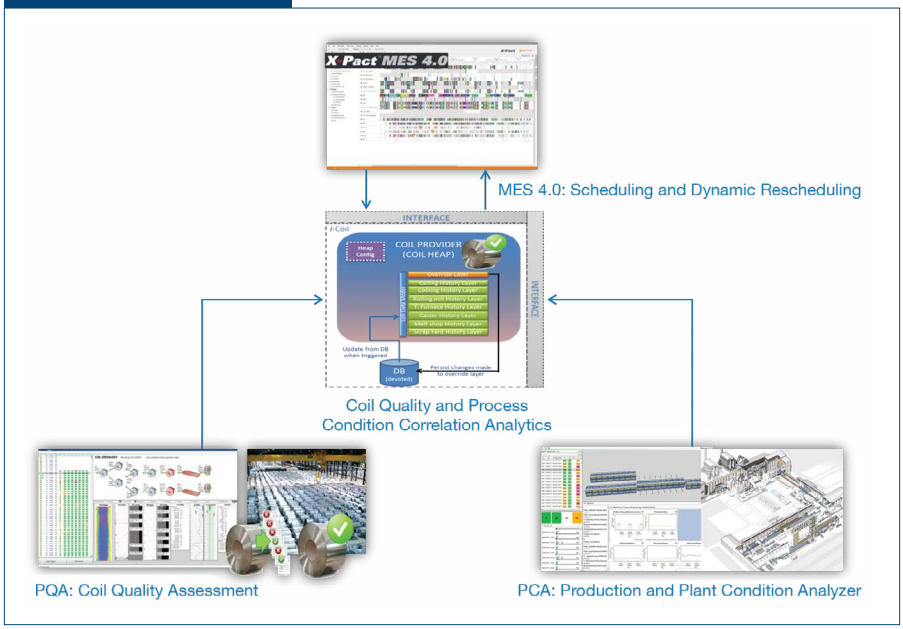
In the second approach, a Production Condition Analyzer (PCA) system has been installed. At the time of this writing, the system is still under construction, even though considerable functionality is already available.

Production Data Warehouse — Together with the SMS group companies SMS digital and QuinLogic, SMS group installed a Product Data Warehouse at Big River Steel. The PDW collects data of measuring devices, the production planning system, process models and technological control systems of the complete mini-mill complex in one place. Based on these data and rules defined by mechanical, media and electrical engineers as well as process and metallurgical specialists, evaluations of the data from different points of view can be made.

Product Quality Analyzer — PQA has been developed as an advanced process and quality management assurance solution.[5–7] It is focusing on the analysis of process data, equipment information, in-line quality measurement devices and trend analysis. It obtains and answers whether the process is running according to definition and expectation and whether the intermediate or final product is fit for further processing or can be shipped as prime material to the end customer. The data and linked analytics can be used from the quality point of view with the PQA to issue quality certificates automatically and semi-automatically.

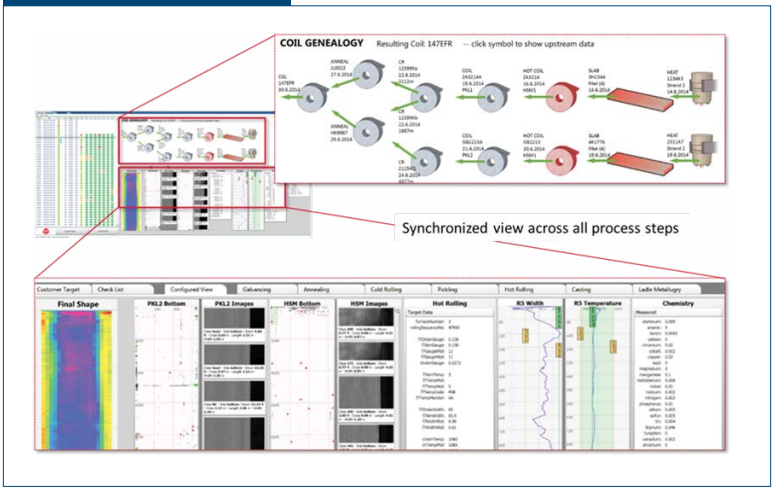
The quality expert is able to get a quick and comprehensive overview about all product and process related quality information over the complete production

Figure 2



Step toward optimizing the product quality using the correlative analytics based on Product Quality Analyzer (PQA) and Production Condition Analyzer (PCA).

Figure 3



PQA — Product quality monitor covering complete process chain (steelmaking to final processing).

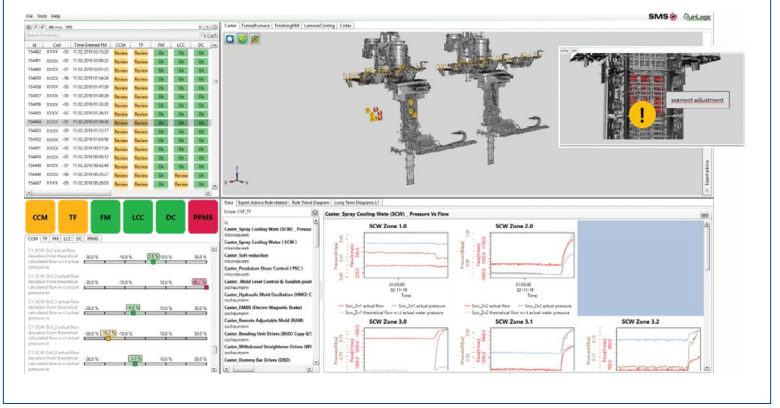
chain, from the meltshop to the processing lines and in combination with a complete coil genealogy.

Based on expert rules, it is possible to make coil release decisions either automatically or manually using the recommendation given by the PQA. PQA is closely integrated with the manufacturing execution system (MES) to allow auto release of coils.

The advantages of the PQA are:

- Combination of expert knowledge and quality management system.
- Evaluation of all coils with defined expert rules.
- Increase of product quality.
- Stabilize prime quality production.
- Decrease rejections by end customers.
- Provide troubleshooting support.

Figure 4



Example of PCA monitor.

Production Condition Analyzer — Using the PDW as a unique data source, the production condition analyzer is able to use many different kinds of data for evaluation such as data from surface inspection systems, technological measuring systems, basic automation, model results, as well as production planning systems.

Evaluation close to real-time and long-term trends and rules allow a short-term notice and information to, e.g., the production planning system for rescheduling as well as investigation of changing long-term behavior. The recognition of a change in the long-term behavior can trigger predictive maintenance actions; "maintenance on demand" rather than just cyclic maintenance activities. Typically, predictive maintenance is obtained by having maintenance personnel observing the equipment, using single charts and analyses.

The production condition analyzer can take over a large part of this manual work and indicate limit violations right in time.

Automatic process supervision and visibility of all process and production-related data across the process chain and early identification of process deficiencies supports the operator and maintenance personnel in process-related decisions and optimized planning of maintenance activities.

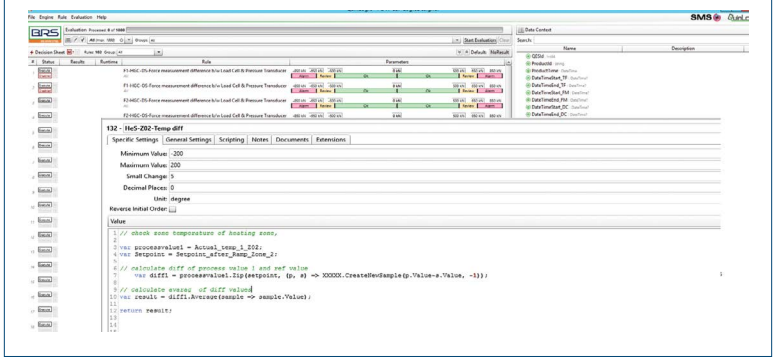
The PCA focuses on production conditions as well as on machine monitoring.

The machine monitoring as one part of the PCA takes into account not only the machinery such as stands, loopers, etc., but also the hydraulics, oil level and leakage monitoring, cooling systems, and the work roll and backup roll states and conditions. This also includes data-based analysis routines that convey maintenance-relevant condition information or forecasts for the respective plant. The results of the machine monitoring system are displayed in an intuitive manner, e.g., they can be displayed with reference to the produced order book, making connections to the products and the quality produced.

In the past, process variables were indicated by various analog meters, alarm signals were hardwired to annunciator panels and multiple hand-controlled devices were spread across large operator desk stations. The process recipes and equipment setups reside in human brains or handwritten on paper. It is the situation when productivity is the primary key performance indicator (KPI), without being

linked to actual process condition and product quality. Tracking process healthiness in-line allows detecting drifts and the definition of optimized process windows depending on many more boundary conditions than before. Linking process condition, machine condition and quality allows for a much better reproducibility and quite specific perks to adjust process quality based on momentarily existing situations. An example would be the measured humidity and temperature to track dewpoints in furnaces for strip production. Being able to track process conditions allows much better reproducibility in product quality.

Figure 5



Example of rule designer.

The evaluation of the production condition and machine monitoring is based on logical process rules. Permanent use and update of growing expert knowledge ensures proper results.

For a better overview, the plant is usually divided into a few areas (e.g., caster, tunnel furnace, finishing mill, laminar cooling, downcoiler).

For each area, a set of logical rules can be created. Basically, all different types of data of the PDW can be used as input values for a rule. The single rule results are consolidated and an overall result is determined for each area.

Creating long-term evaluations allows recognizing tendencies of plant, equipment and plant behavior.

For a typical rule, to verify the plant status:

- Check load condition of drives, check whether no load torque is too high.
  - If there are no load torque increases, give the recommendation to check/exchange bearings, etc.
- Long-term check of flow of laminar cooling valves:
  - If the water flow decreases, the valve/tube might be clogged or worn out.

Information about the rule results are given on a user GUI (graphical user interface). At the GUI there is an indication of which rules determined deviations from the normal behavior. In the 3D plant model, the area is highlighted that caused the problem.

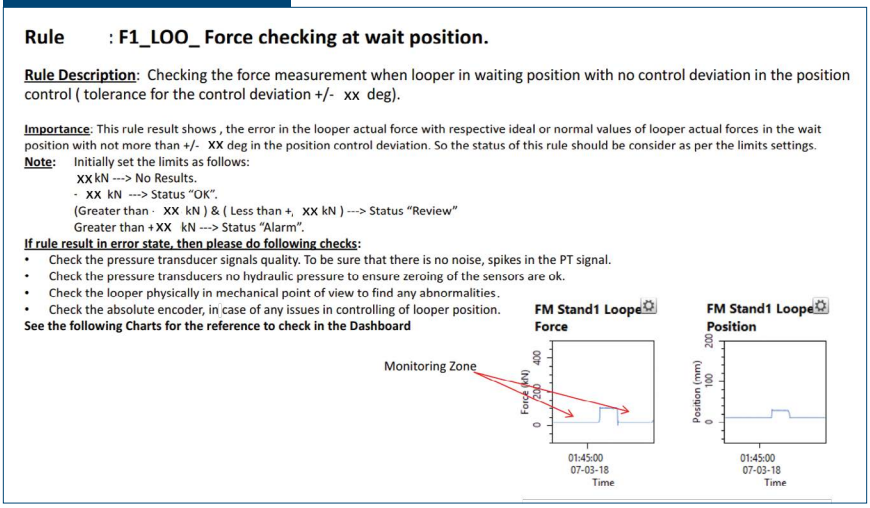
Creating and enabling rules is easy. Of course users can create, modify and activate rules. User management allows handling of access privileges as well as revision control.

For most of the rules, operators or maintenance personnel can retrieve more information regarding the rule evaluation and the rule result by opening the associated expert advice. Information is provided on what to check and how to proceed.

PCA Webpage — From a maintenance perspective, it is important to have quick access to maintenance-related plant and process status information, while being on the way through the plant. The PCA webpage allows having the information at hand wherever needed.

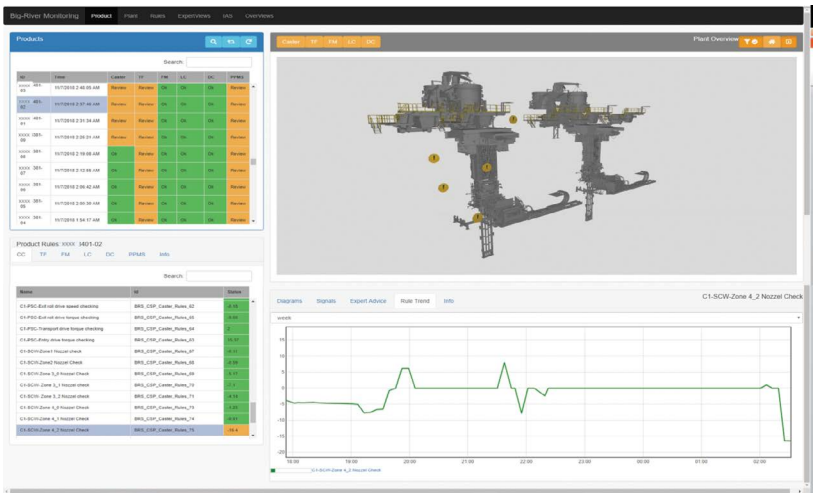
The PCA webpage shows the same information as the PCA monitor, including rule results, the 3D plan model with indication of the problem area, expert advice, charts and trends.

Figure 6



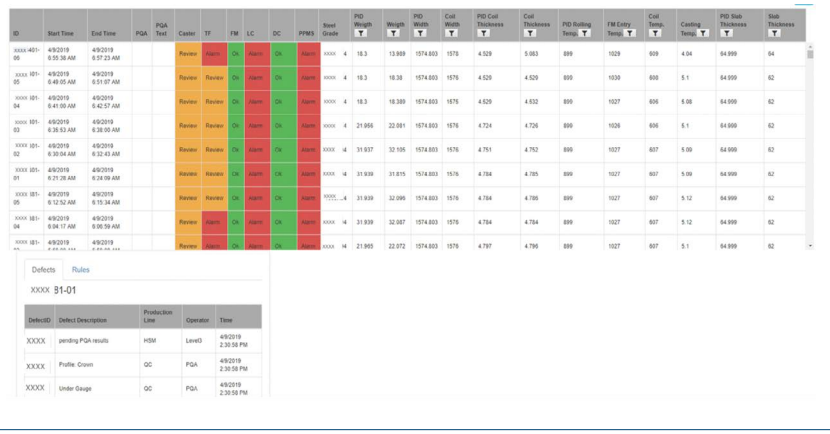
Example of expert advice.

Figure 7



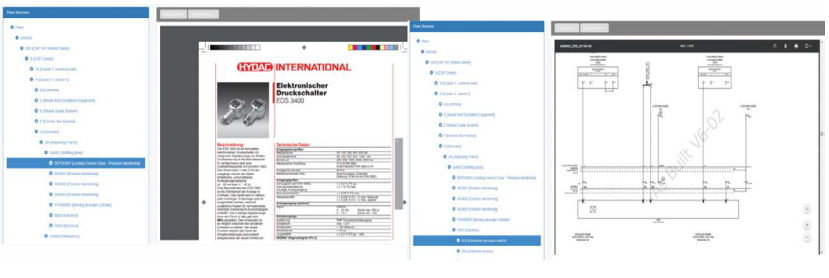
Example of PCA web front end.

Figure 8



Combined view to quality grading results, process condition evaluation results and product data.

Figure 9



Data sheets and electrical circuit diagrams are linked to the SMS Information Model.

PQA and PCA Results on One Common Webpage — With respect to the final aim — to identify relations between plant status/production condition and product quality, it is helpful to have the results of both systems on one screen. Since everything is provided out of one hand — PDW, PQA and PCA — a web view can be set up easily.

The combined view with the PQA and the PCA provides a good basis for evaluating product quality problems versus plant status. The view and filter mechanisms allow fast and easy evaluation of potential relationships between product quality and plant status. Thus it helps to gain more expert knowledge, create new rules and define parameters for AI modules that use pattern recognition, etc.

PCA Webpage With the SMS Information Model — Using the PCA to analyze an equipment to be faulty will lead to the need for more information about the particular equipment. If replacement becomes an issue, the physical location of the devices, data sheets, manufacturer's information, electrical drawings, disposition drawings, bill of material and, e.g., warehouse storage location have to be identified quickly.

Therefore, an information model comprises data of the engineering process, information of the actual plant, expert advice, links to other documentation like electrical drawings, data sheets, etc. The electrical drawing, the datasheet, etc., can be accessed directly from the GUI.

The SMS Information Model can easily be extended by the customer to include more information or documents. Modifications can be done on the fly.

Additional Features of the Information Model: Linking eDOC System and IMMS to the SMS Information Model — The SMS Information Model can be linked to the SMS eDOC

system (electronic documentation management system). Equipment-related identification is stored in the eDOC system so mechanic or hydraulic drawings can be found easily and quickly in the documentation management system. By linking the information model to the SMS group IMMS (integrated maintenance management system), the information about the problem area can be submitted. Equipment-related identification is transmitted to the maintenance management system, too, allowing the IMMS to create work orders with all of the necessary information. The PCA evaluation of the long-term behavior of the equipment helps to schedule predictive maintenance activities.

Outlook

Even though some steps have already been made regarding digitalization, the end is not completely visible.

As one step, the different sources in a steelmaking plant such as PQA and PCA, MES, predictive maintenance, energy advisor and design data are correlated and made available. Today operators, quality and maintenance specialists use it. The data usage is also subject to AI evaluation.

Conclusions

Focusing on the aim of the learning steel mill, some successful steps have already been made.

First achievements: The PQA is a fully operational product and in service on all production lines. The PCA is a new product showing good results; further areas are under construction. The system is helping to ensure stable and high-quality steel production with minimum cost and human efforts. The database provides an ideal platform for current and future AI projects.

As supplier of the whole chain (technology, mechanic, electric, automation, digitalization, production planning, quality evaluation, production condition analyzing and AI applications), the relations between the different data are known, and this knowledge and the possibilities and advantages of digitalization will be used to move toward a learning steel mill.

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