The digital future in long steel production – predictive quality

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Abstract. Swiss Steel AG, the competence centre for the manufacturing and processing of engineering and free-cutting steels within the Schmolz+Bickenbach Group, has ordered as one of the first long product manufacturers the knowledge-based PQA system (product quality analyzer) from MET/Con. The PQA carries out online analyses of process, production and quality data from steelmaking, rolling right down to the drawing process which is executed at Steeltec AG. The modular software concept includes expert rules which evaluate quality relevant process data supporting release decisions for the next processing step. The correlation module covers latest features of mathematical evaluation methods, which can be used directly for process optimization. This industry 4.0 pilot project is a big step in the quality prediction of long steel products. The modules and their implementation within the process chain are shown, together with experiences from commissioning and first operating results.

Introduction

The production site of Swiss Steel AG is located in Emmenbrücke, Switzerland. One of the largest customers, Steeltec AG, is located on the same site. Steeltec AG is a producer of bright bars and also part of the Schmolz+Bickenbach group.

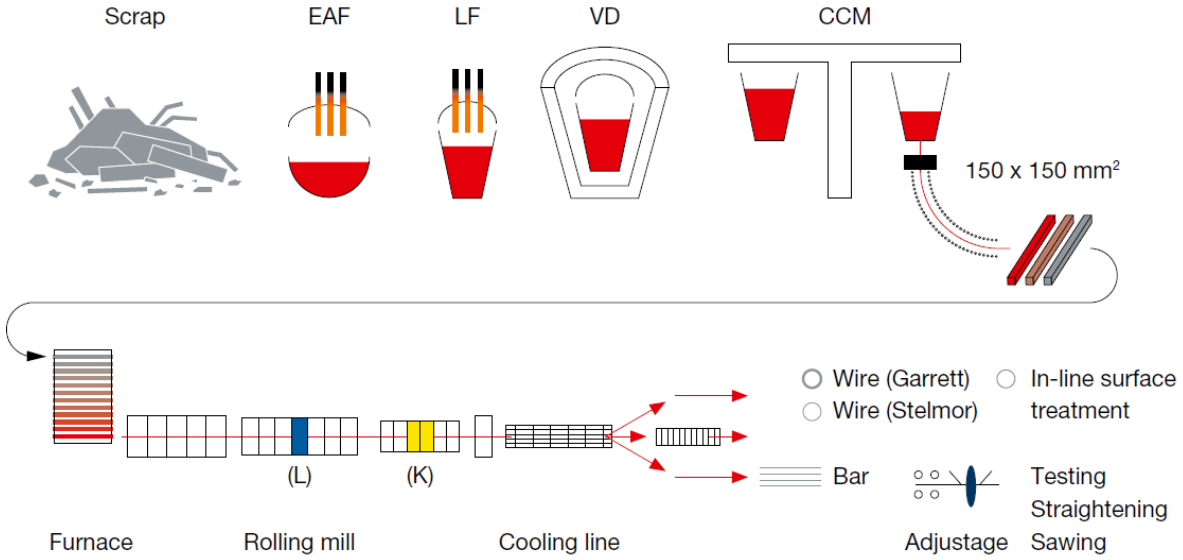

Fig. 1: Process chain of the Swiss Steel AG

The production facilities of Swiss Steel AG include a melt shop and a rolling mill.
The process route in the melt shop consists of an Electric Arc Furnace (EAF), a Ladle Furnace (LF), a Vacuum Degasser (VD), and a Continuous Casting Machine (CCM).
The products of the melt shop are billets with a size of 150x150 mm^2 and a length of 10.8 m which results in a weight of approx. 1.85 t per billet.

The continuous rolling mill starts with the walking beam furnace for reheating the steel billets, followed by the roughing, intermediate and finishing rolling line. After the finishing line (Kocks-Block) the rolling line is divided into three different lines for the production of wire rod (Stelmor), bars in coil (Garrett) and bars. The diameter range for the Stelmor line is from 5.5 mm to 17.5 (22.5) mm, for the Garrett Line from 18.0- 45.0 (50.0) mm and for steel bars from 16.0-66.0 mm.

Steeltec AG is equipped with drawing and peeling lines. Swiss Steel supplies both steel bars and wire rod to Steeltec. One of the most important products for both companies is the high-strength free-cutting steel ETG®. The majority of final customers are OEMs which put demanding requirements on the surface quality of machined parts. Therefore Swiss Steel and Steeltec make great efforts to minimize surface defects and set high standards in the non-destructive testing.

Those trends have lead to high internal quality costs, mostly caused by surface defects. In order to minimize those costs, statistical analysis has been carried out in every process step. However, in many cases the time consuming analysis of data from separate sources has not lead to satisfying findings. In order to overcome those limits, a new approach had to be chosen. Recent developments in the field of digitization have opened up the possibility to tackle the problem with a big data solution.

Goals

The main goal was the reduction of quality costs by optimizing the process parameters based on data analysis. For this purpose, a big data quality tool integrating and joining data across the production process from Swiss Steel (supplier) and Steeltec (customer) was chosen. The goals can be summarized as follows:

- "Big Data" solution → collect and join data across plants and apply new statistical methods
- Integrate both aggregated and high-resolution data as well as proprietary data formats
- Include data from the customer
- Reduce time for data preparation and joins
- Digitization of quality decisions and quality reports

Implemented solution - PQA

PQA (Product Quality Analyzer) has been developed by QuinLogic and MET/Con, which are part of the SMS group. The software tool has a modular architecture. The backbone of the software is the PDW (Production Data Warehouse) that integrates and stores the process data. At Swiss Steel AG and Steeltec AG the following modules have been implemented:

QualityMonitor
Essential part of the PQA system is the QualitorMonitor. It acts as an integrative interface between the operator or quality manager, the software and data warehouse. The Quality Monitor provides comprehensive and compiled information. It is a customized information exchange platform.

LogicDesigner
The LogicDesigner serves to define the quality relevant rule set. Besides the definition of quality rules, it also enables the user to simulate the outcome of the application new rules or modifications of existing rules on the existing process data.

Analysis & Reports
The Analysis & Reports module is a web-based tool to generate customized reports based on the data from the PDW for different user groups.

DataCorrelator
The module DataCorrelator uses the data available from the PQA® system for further analysis. An intelligent software library provides various statistical methods of examination for data correlation. Troubleshooting with this module is performed most efficiently on the historical data set of a particular set of variables (such as suspicious parameters or process areas). DataCorrelator allows easy selection of variables, simple sorting of the data to be checked, and processing with a secure strategy (data flow limitation and priority ranking). Therefore, the network and database capacities are not overloaded. For a meaningful cause analysis, the data are prepared and/or corrected. This clean-up functionality is an essential component of the DataCorrelator module. The exclusion of implausible data or their replacement by a configurable value is possible [1].

Data sources and integration

The integrated data sources can be divided into four groups. In general both aggregated and high-resolution data were integrated into the PDW. The purpose of the integration of data in high-resolution was to correlate the local process parameters on each billet with any possible local defects. Prerequisite is the consistent material tracking and genealogy from the billet to the coil and the drawn bright bar.

The PDW is a local database solution running on a separate virtual server in the existing hardware environment. It stores 1:1 copies of all the data sources for several years. This principle reduces the load on the original databases when executing complex data queries or correlation analyses.

Swiss Steel AG steel mill
Besides the aggregated Level 2 data, also data in higher-resolution were integrated into the PDW. The data in higher-resolution comprises different Level 1 signals like stopper trends or mould level trends from the CCM and the data of a scanning pyrometer that monitors the temperature of the four strands.

Swiss Steel AG rolling mill
The rolling mill information includes process data from Level 2 (both aggregated and in high-resolution) and measurements from two stand-alone systems, namely the in-line eddy current testing and the dimension control.

Steeltec AG drawing line
The most relevant data of the drawing line are the test results of the eddy current surface inspection system. These provide the final quality decision of the whole process.

Overall data sources
Additionally there are also Level 3 and Level 4 systems (MES and ERP) involved, which contain general information. Examples include material tracking information and header data. Results from laboratory material tests (e.g. chemical composition, mechanical properties) from Swiss Steel and Steeltec are stored in another database which has also been integrated into the PDW.

First results and experiences

In a first step, the existing quality manual was digitized with the LogicDesigner into scripted rules. The LogicDesigner allows simple quality rules on the one hand, for example checking if the reheating temperature is in the desired range. Those rules can be easily modified using a digital slider bar. On the other hand, it is also possible to implement complex rules with the help of the LogicDesigner scripting language LINQ. LINQ is a query language that has been integrated into the .NET framework and can be used within the syntax of C# and VisualBasic. Such rules can process multiple signals and data from different fields and also apply mathematical functions. They can be customized for different customers, steel grades, surface quality classes, etc.

The application of the quality rules on the process data results in a quality decision (“OK”, “REVIEW”, “BLOCK”) for every single product. A product can be an entire heat or production order but also a single billet or coil. In the production process of Swiss Steel, quality decisions are made after the casting process and after the rolling process.

For the casting process, two quality decision levels were implemented, namely the heat level and the billet level. On the heat level, data like chemical composition or hardenability are evaluated, whereas on the billet level local parameters like mould level are considered.

In the rolling process, the quality decisions are also made on two levels, one for the entire production order and one for every single coil. On the level of production orders the results of cold heading samples are evaluated for example. On the coil level, the results of the inline eddy-current surface inspection, the dimension control and the pyrometers among others are the base for the quality decisions.

In a second step, the data are analyzed and correlated in order to identify and optimize process parameters in case of quality problems. The current version of the DataCorrelator is a new release from QuinLogic that uses the state-of-the-art algorithm C4.5 to identify relevant process parameters that influence the final result. The result of such a correlation analysis is a decision tree, a series of hierarchical stacked if-else clauses, displaying which parameters lead to a certain result [2]. In order

to improve the practical applicability of the DataCorrelator, the first ETG® data sets were analyzed and issues were identified as new input for the development of the module.

Once relevant and optimized parameters are identified, the corresponding if-else clauses can be exported to the LogicDesigner as a quality rule. The LogicDesigner offers a simulation function, where new or changed rules can be tested on the existing data of the PDW before implementation. The result of the simulation indicates the blocked number of coils/heats etc. would change if the new rule was implemented.

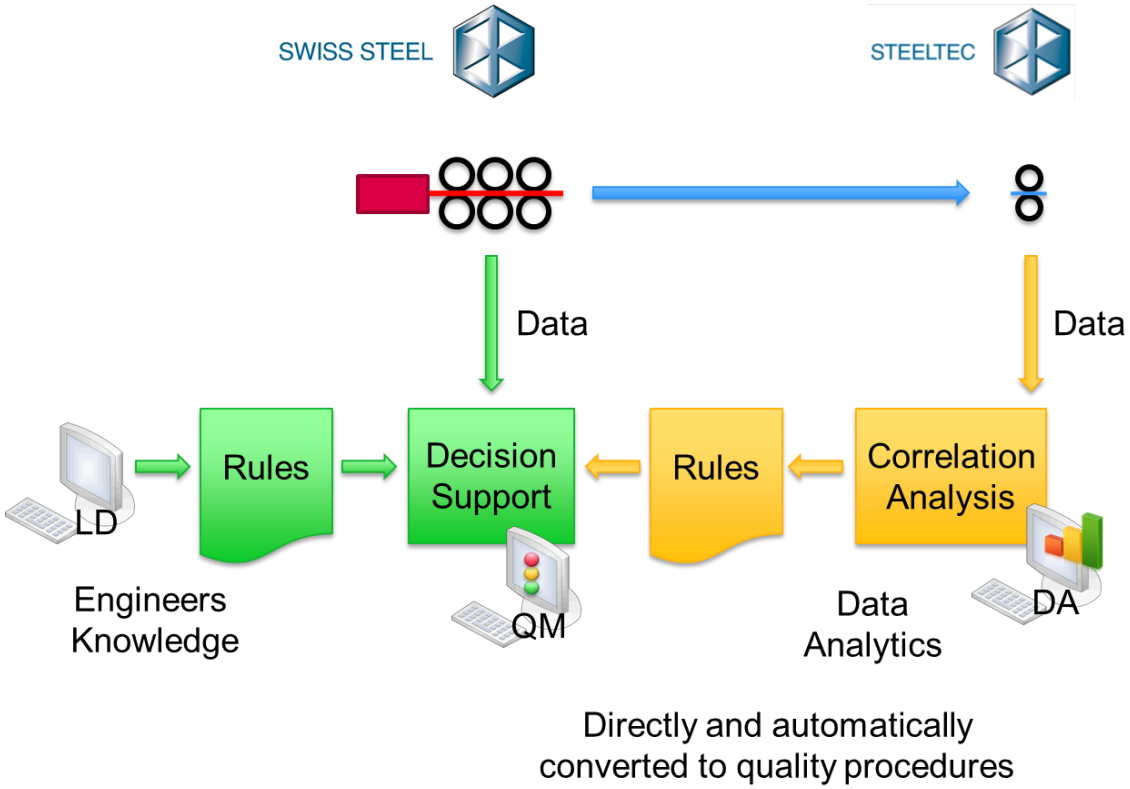

Fig. 2: interaction of the PQA modules

Summary and outlook

In order to further improve the quality and meet higher customer requirements, with focus on the Steeltec special product ETG®, a digitization project across the value chain of Swiss Steel and Steeltec has been initiated. The approach was to collect all available process data in a central data warehouse and utilize the data with the modular software PQA. The data includes aggregated and high-resolution data as well as proprietary data formats.

In a first step, the existing quality manual has been digitized as quality rules with the programming language LINQ. In order to display the data and quality decisions, so called QualityMonitors have been customized for the melt shop, rolling mill and the drawing line. The data warehouse also enables big data analytics without time consuming data joining and cleaning. This functionality is provided by the module DataCorrelator. It applies the state-of-the-art algorithm C4.5 to identify relevant process parameters that influence the target value. First results have been collected with data sets of ETG®, which also helped to adapt the DataCorrelator. The next steps include the application of the algorithm on other products and the design of a first QualityMonitor on shop floor level.

References

[1] J. Kempken, T. Hülper, PQA – The Success Factor to reach next Performance Level in Operation, ABM Conference, Sao Paulo, 2017

[2] M. Schmitt, internal training material DataCorrelator, QuinLogic GmbH, 2018