

# SIROLL TCOPTIMIZER<sup>®</sup> PROCESS EXPERT SYSTEM FOR JUST-IN-TIME WARNINGS AND DECISION MAKING<sup>1</sup>

Laurie Bonhomme<sup>2</sup>  
Benoit Jalard<sup>3</sup>  
Stéphane Georges<sup>4</sup>

## Abstract

Worldwide steel manufacturers are constantly looking at increasing productivity while maintaining quality at the highest level. This involves a perfect control of the whole steel production chain, a reliable production monitoring and finally a good knowledge of customer needs. Siemens has developed a solution for an efficient follow-up throughout the complete steel processing consisting of an advanced software helping line managers as well as operators and maintenance people in the daily handling of a processing line. Thanks to embedded steel process business logics and rules, the hundreds of signals coming from the whole metallurgical route (from casting to downstream process) are combined together into valuable information making this software more than a classical condition monitoring system. This information is then stored in a single database where it can be consulted in an easy manner through final user-oriented screens. Monitoring all the working parameters and steel quality along the entire steel making process may turn out to be a challenge and when the time comes to transform them into valuable information able to trigger relevant just-in-time warnings, the task suddenly seems overwhelming. Siemens meets this challenge with a solution that allows setting up process parameters conditions for defined grades, quality control of the products coming out of processing lines or triggering of early warnings against performances degradation regarding equipment conditions, process and product quality. With special focus on recent projects, the article presents this expert system (concept, technological solution and embedded production knowledge) that leads to improved end quality production.

**Keywords:** Expert system; Monitoring; Metallurgical knowledge; Just-in-time warnings; Steelmaking process.

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<sup>2</sup> Dipl.-Ing., Metallurgist. Siemens VAI Metals Technologies SAS. France.

<sup>3</sup> Dipl.-Ing., Siroll TCOptimizer<sup>®</sup> Product Manager. Siemens VAI Metals Technologies SAS. France.

<sup>4</sup> Dipl.-Ing., Product Lifecycle Manager for Processing Lines. Siemens VAI Metals Technologies SAS. France.

## 1 INTRODUCTION

With the given economic situation, steel makers look more closely at their production quality and try to respond as quickly as possible in case of non-conformity. To assist them, Siemens has developed an advanced software for just-in-time warnings that helps line managers as well as operators and maintenance people in the daily handling of a processing line. In a metallurgical environment, production quality goes hand-in-hand with a good line driving, the knowledge and the feedback of the upstream process, the management of production orders. To achieve this quality whilst retaining a high level of profitability, production lines are nowadays equipped with thousands of sensors to permanently track possible production deviations.

## 2 THE AGE OF BIG DATA

Beginning of 90's, hard drives size was quantified in megabytes. Just 10 years after, the volume of data is exploding. According to Kryder's law,<sup>(1)</sup> the hard drive capacity is linearly increasing over time and increases by a 100-factor every 10 years. The term gigabytes (10<sup>9</sup> bytes) has been used and nowadays, we talk about terabytes, even petabytes, for storage units. And of course, the amount of created data goes hand in hand with amount of available space. Parkinson's law<sup>(2)</sup> tells us that data expands to fill the space available for storage. Taking account of all the worldwide sources of information, every day, we create 2.5 x 10<sup>30</sup> bytes of data, so much that 90% of the data in the world has been created in the last 2 years only.

The steel-making industry is not an exception to the rule. The metallurgical plants with their fully automated hot/cold mills and processing lines are now equipped with countless digital sensors that can measure and communicate dimensions, speeds, temperatures, ... creating an era of data abundance stored in large scale database of various process automation system (Level 2). Looking at every signals coming from these sensors to deduce the hypothetical failure of a specific equipment, following up a production consisting of several process stages or even giving the historical background to a produced coil usually becomes a nightmare, even for experts who finally get utterly lost in that ocean of data. To handle Big Data from the steel-making industry, Siemens process expert system includes a computing intelligence highlighting relevant events without overwhelming users by gigabytes of data.

## 3 CONCEPT

Siemens expert system is a central tool which collects data and signals from all parts of the production chain. As a non-exhaustive list, let's hold up as examples among others the production data (line speed, furnace temperatures, skin pass rolling force, zinc bath chemistry...), the product data (strip width, thickness, profile, chemistry, ...) and further data (gas consumptions, fan speed...). To varying degrees, all these data bring their contribution in the production quality control and the way to analyze them is of importance. A first method would be to determine the critical parameters and study their individual variations. This method is not reliable as interactions are not considered. A second way would be to analyze their variations from a statistical point of view, which is also not fully satisfactory as it does not offer an accurate overview of the events happening during production, nor to determine the root causes.

For these reasons, the solution is based on a so-called Business Rule Management System (BRMS), which logic is used to detect incidents as early as possible and

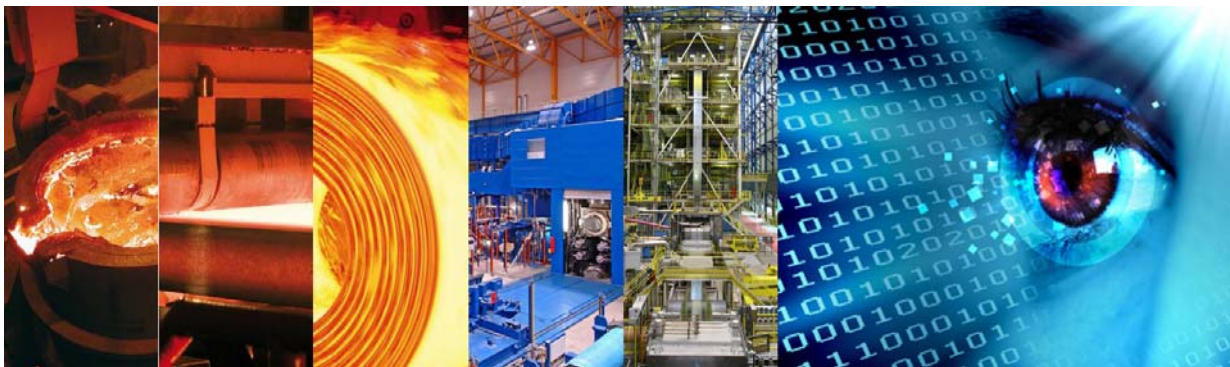
prevent emerging anomalies. By the means of a business vocabulary syntax (“thickness”, “width”...), simple logical expressions (“And”, “Or”, “If”...) and decision trees, the BRMS allows non IT-specialists to handle the incoming signals and create some rules, also called business rules. Each rule follows the following similar pattern:

- Incoming signals validation
- Signals filtering and storage in local database
- Combination of signals according to the defined rule
- Alarm triggering if defined thresholds are violated.

Thanks to this system, the analysis of a huge amount of data coming from almost fully automated metallurgical plants becomes much easier.

#### 4 WHOLE PRODUCTION CHAIN MONITORING

The highly demanding car market needs constantly increase the steel quality in terms of strip dimensions, mechanical properties, coating and surface aspects. Getting the final required metallurgical structure is the result of a succession of process steps all along the production route, that have individually a high influence on the final product quality. To reach the quality required, focusing only on final processes is necessary but not sufficient. The whole production route (including upstream processes) has to also be monitored (Figure 1). At last step processing stage, thermal metallurgical cycles, furnace atmospheres, zinc pot chemistry, free surface defects, deflector rolls, sensors drift, ... must be carefully controlled, and adjusted, to reach high demanding car market needs.



**Figure 1.** Siemens process expert system looks after the whole metallurgical route.

The software firstly collects not only data from the line where it is installed but also data coming from related processes (hot strip mill, pickling and cold rolling lines and processing lines). For a better efficiency, data from laboratory, automated surface inspection device and online mechanical properties measuring device are used as well. Depending on selected data collection strategy, strip properties may be collected either from lab or from in-line gauges (real time approach versus data precision). The BRMS rules then transform gigabytes of rough and unworthy data into relevant warnings against soon-emerging problems and identifies their root causes.

To understand what exactly a business rule is, let’s take the example of the ‘Risk of material with coarse grains’ rule for a continuous annealing line. This rule considers the following input signals: strip section, temper mill roll force, furnace strip speed and soaking temperature.

The system evaluates their values and answers the next 4 questions: do we have a low process speed? a furnace temperature outside a defined range? a significant drop in temper mill force? a significant variation in the strip section? Taken individually, these signals do not carry any valuable information. However, in one combined, a relevant information can be generated. If all the criteria of the rule become simultaneously true, the business rule becomes active. From a metallurgical point of view, there is a risk of producing material with coarse grains due to a too high annealing temperature, resulting in a mechanical properties drop. The system highlights then out of range signals and generates an alarm.

## **5 ORIENTED USERS SCREEN**

Siemens process expert system has been designed to be a multi- users software with dedicated screens for both production and metallurgist people. A special effort has been made on the ergonomics to produce very few disturbances to the operators, target being to display only relevant alarms for soon-emerging issues. The main screen therefore remains empty most of the time. This explains why the operator screen is also called "Blank Screen".

Regarding the metallurgist screen, this one opens the door to in-depth examination as all relevant parameters of the metallurgical route are gathered in a single screen. The whole metallurgical history of the product from the hot strip mill down to processing lines is thus exposed in an instant to the metallurgists gaze. With such an arrangement, only few mouse clicks are required to detect quality issues.

The typical configuration consists of seven frames (Figure 2) with the following features:

- ❶ Coil selection and search module
- ❷ Coil related data (primary data, presets, ...)
- ❸ Abnormal events (out of range rule parameters, ...)
- ❹ All coil- or time-related available measured signals
- ❺ Tracking data (product life follow-up between hot strip mill, tandem cold mill and processing line)
- ❻ Graphical area displaying selected signals
- ❼ Chemistry, furnace cycle and heat treatment data.

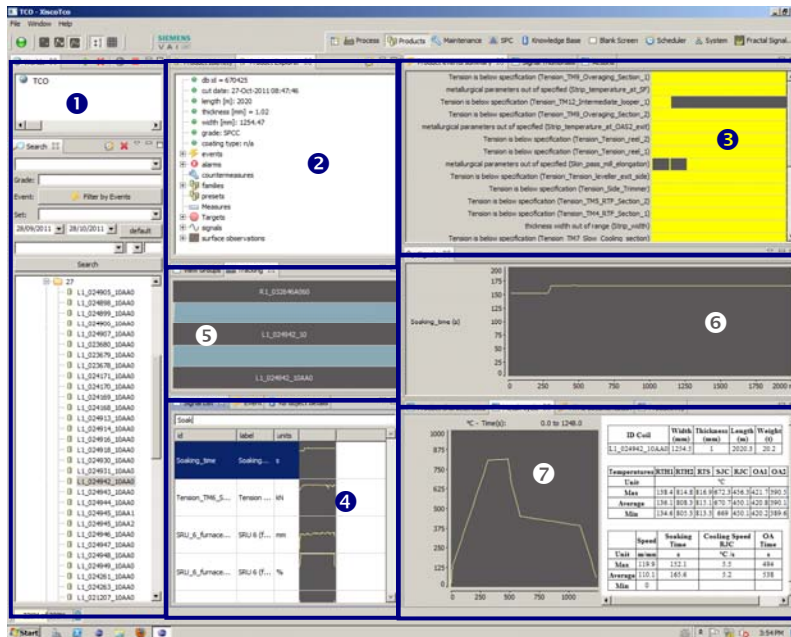


Figure 2. Metallurgist screen with the different functionalities.

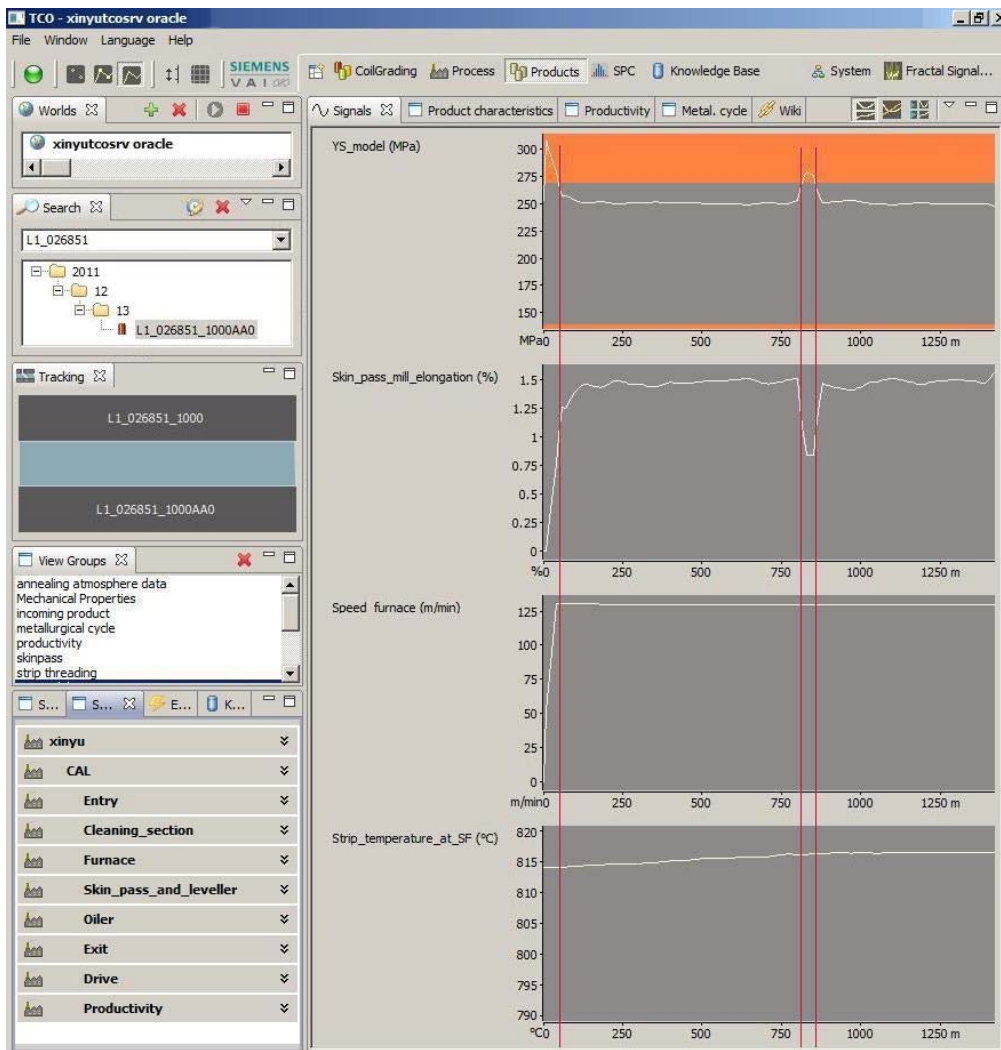
## 6 EMBEDDED KNOWLEDGE

Compared to a statistical data analyser or process data acquisition system, Siemens process expert goes beyond and offers complete supervision and optimization functionalities of the whole metallurgical production route. The BRMS not only includes initial rules developed by process and metallurgical experts but also a user-friendly runtime environment so that experts have the possibility to improve existing rules or create new ones. Thanks to its scalability, the software abilities will grow to become more efficient day after day throughout its use.

Another smart aspect is its ability to share experience thanks to an embedded wiki database. The software uses the same principle of the well known free encyclopaedia which allows its users to add, modify or delete its contents to serve knowledge management. This functionality allows any user to share his experience with his colleagues. Each encountered problem can be described, stored and reminded if the situation happens again.

So as to meet its customer expectations, Siemens recently added an extra-feature, the so-called coil grading module. This component tracks all the parameters falling within the scope of the coil quality assessment and computes a global quality level based on final customer requirements. Thanks to connection with advanced gauges such as automated surface inspection systems, a full product grading (global mark or mark per section like head, tail, top/bottom side) is possible. This calculation is based on the difference between the scheduled technical targets and what has been really achieved.

The previous described yield stress model is for instance used, as an input for the coil grading, to evaluate the material yield stress along the strip length and the output is compared to the target yield stress. The fig. 3 indicates the portions of the strip with mechanical properties out of range.



**Figure 3.** Coil grading module showing strip portions with mechanical properties out of tolerances.

As the software presents in an easy and organized manner the whole product information and its related production conditions, what happened on site becomes crystal clear. Using a remote connection to the software server, Siemens teams are in position to offer the following assistances: development of new business rules for a better production monitoring, development of new steel grades, stabilisation of the production of already existing steel grades, production data analyses and consulting.

## 7 IMPLEMENTATION AND RESULTS

Tianjin Tiantie Metallurgical Group (TTMG) and Xinyu Iron & Steel Co. Ltd (fig. 4) awarded in 2008 and 2009 Siemens contracts for the supply of new continuous annealing lines including this process expert system, mainly to develop the production of high grade strips. To be efficient, the software needs to collect signals from the whole metallurgical route (from upstream process down to laboratory). In the case of TTMG project, one of the challenges was to get upstream data as hot and cold plants where geographically separated by about 500km. Thanks to the close cooperation with the steelmaker's IT infrastructure and operating personnel, the software architecture implementation only required 7 weeks in total, split in to 2 missions. The first one of 4 weeks was for software and its hardware equipment (server, PCs...) installation. The second one of 3 weeks was dedicated to employees

training, to get the most of collected data and to implement new rules defined by users and customer experts.

Meanwhile, Siemens metallurgist experts visited the upstream installations of these 2 steel makers so as to have a good knowledge of the upstream processes and understand the way they are used. After the plants visits, a list of recommendations was issued to help to control end steel quality. With their experience, Siemens experts were able to develop tailored business rules for each of these 2 steel makers. Once the implementation was completed, this process expert system has proved to be a useful tool during the commissioning steps, for the production ramp-up and for achieving desired steel quality.



**Figure 4.** Already two customers for Siroll TCOptimizer<sup>®</sup> process expert system.

To illustrate its whole interest, let's now go through 3 real situations that happened on site. In our first example, the 'Mechanical properties out of range' alarm suddenly appears on the operator screen. By physical measurements, the lab rapidly confirms the abnormal mechanical properties (yield stress out of range). Using the metallurgist screen, the hot strip mill coiling temperature is immediately highlighted as key parameter. In the signal list, its time-related graph shows that the temperature is out of operational limit (range: 600-700°C, actual: 550°C). Knowing now the root cause, process operators can implement a local solution – at the annealing line level – to compensate upstream dysfunction. In this case, they increase the annealing temperature.

In the second example, a similar situation happened within the framework of two identical projects with the difference that in the second one a the software solution is installed on the line. For the project without the software, the team faced with guiding troubles for some coils. After months of investigation, the root cause was found, namely deviations in strip profile at the hot strip mill. In the second project, as the software recorded the strip profile for each coil at HSM, the investigation was completed in few hours.

The software stores gigabytes of information that can be easily formatted and exported to perform process optimization. In that last example, it was found that the furnace soaking temperature could be decrease by 20°C for all coils of a particular steel family whilst keeping the end-product quality. This action led to substantial savings.

## **8 CONCLUSION AND OUTLOOK**

Siroll TCOptimizer<sup>®</sup> process expert system includes various modules which allow different types of operation: data recording and visualization, just-in-time alarms and warnings regarding product quality and process, automatic and systematic data processing product grading, knowledge management, remote assistance by Siemens specialists. With all its functionalities, the presented solution is a unique expert system allowing a large amount of possibilities to monitor lines for demanding steel makers. The success story goes on and in 2013, it will be installed on a direct rolling annealing and pickling stainless steel line in China

## **REFERENCES**

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