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Implementing a quality execution system for two steel works of Shougang, China

The implementation of the quality execution system at Shougang Corporation required just three months. As a major outcome, every coil at every production step has now a quality certificate, held online on a server for five years. A second outcome is a portable digital quality “manual” describing all key criteria for all products and grades. The implementation has been a joint effort of production management, quality assurance, automotive customer sales department and the IT of Shougang Corporation with QuinLogic.

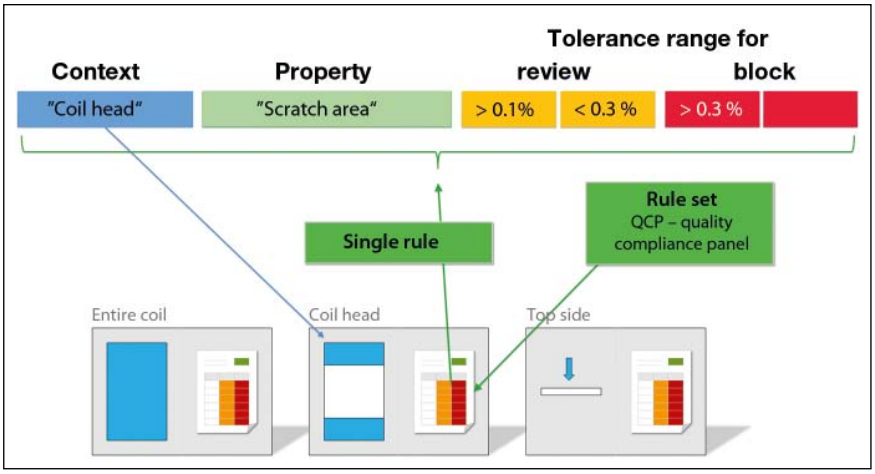

Figure 1. **Rule principle of the QES**

Shougang Corporation (formerly Capital Steel) is one of the leading steel makers in China and among the first to implement China’s government directives for improved steel quality. As a key activity, a quality execution system (QES) was purchased and installed at two sites (Qian’An and Shunyi). Both sites are part of the production chain (steel making, casting and hot rolling in Qian’An and pickling, cold rolling and galvanizing in Shunyi). The requirement was to implement an integrated system linking all production lines and the two sites with an integrated software to perform deterministic computer controlled quality decisions and making the results available throughout the entire process chain.

With now more than one year of operational experience, conclusions about the efficiency of this computer controlled process can be made. Beyond that, the resulting quality data will in the future be presented using web/html services.

Objectives of the QES project

To achieve best supply mainly for automotive customers, Shougang has put strong emphasis on information technology. In particular the Shunyi site has been equipped with state-of-the-art enterprise resource planning (ERP) and manufacturing execution system (MES) software. Data sharing and a software system to determine the line quality, comprehensive product information, integrated quality management, planning and scheduling have been set as priorities.

The objective for Shougang was to qualify for premium automotive customers with highest quality assurance standards. Such customers demand a quality system in place for certified and fully documented quality. Manual quality assurance processes do not fulfil these requirements. Furthermore, the use of advanced gauges such as surface inspection systems (SIS) and online roughness gauges are driving the move from manual to semi-automatic software-controlled quality processes. Such gauges deliver vast amounts of data. The tasks of digesting the data and drawing conclusions are almost beyond human capabilities, not even considering combinations of results from several gauges. Shougang decided to utilize all these data efficiently via software. The result of a worldwide search for applicable software was the selection of QuinLogic’s quality execution system (QES).

The overall quality assurance system at Shougang follows a five level approach:

- material data collection (LIMS, SCADA, SIS, gauge databases),
- online quality grading system (QuinLogic’s QES, online in 2010, planning started in 2008),

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– overall quality information query system (ongoing development),
– integrated quality planning and rescheduling (planned, MES/ERP level),
– integrated quality management (planned).

At the Qian'An site, the QES had to cover:
– two casters and
– two hot strip mills (2,160 mm, 1,560 mm).

At the Shunyi site the QES had to cover:
– one pickling line with coupled cold rolling mill (PLTCM),
– one continuous annealing line (CAL),
– two continuous hot-dip galvanizing lines (CGL).

Before using the QES, quality was mainly determined manually. The Qian'An site employed a self-made slab grading system and a purchased software package. The QES objective was to replace all existing procedures and become the only system for all process steps with centralized control. A key requirement in addition to this centralized approach was a superior connectivity for the QES. Examples of special data sources are:
– inSQL real-time data from cold rolling,
– iba real-time data from casters and hot mills,
– Oracle data (MES information, PSImetals),
– all SIS brands (ISRA Parsytec, Cognex, Siemens-VAI).

Displays were to integrate all these data sources and allow Chinese language manual input and Chinese language configurable reports. Quality reports and certificates had to be created for every coil and every process step, and online availability for five years was required. The objective for these reports is obvious:
– protecting downstream process steps (and ultimately the customer) against faulty material,
– documenting all details of quality assurance for a coil throughout the process chain, including the transition of coils from Qian'An to Shunyi.

Besides the requirements on data connectivity and IT architecture (centralized servers per site), the major challenge was to complete the project for both sites in three months, including the grading rules. Since the start-up of the QES, Shougang has been actively approaching automotive customers, with the first sales conference on automotive steel grades in September 2010.

QES architecture and rules principles

The basic architectural element of the QES is the quality rule. Rules are widely known to govern quality decision processes. QuinLogic is among the first to implement rules with innovative concepts such as contexts and feedback/verification functions. **Figure 1** shows the rule concept. Of course, rule results as well as result ranges and their assignment to results of a rule are customer specific. In case of the Shougang cold mill, up to 11 differentiated results have been used. The context can limit the rule application to certain coil sections (e.g. top side or head section) as well as to certain grades, customers or process lines. The individual results are tied together to a complete coil result with selectable criteria (e.g. worst rule result determines coil result). Rules can also trigger individual actions, e.g. sending a telegram (alarm notification). This mechanism also allows the "misuse" of rules to monitor process conditions (conditional monitoring system – CMS).

Data is retrieved from all connected devices and databases. To implement this, the data mapping layer uses an XML based meta data definition script called "data context". Within this data context, data sources can be specified as well as data aggregations, calculated virtual databases and data alignments. The connectivity layer features various modules including access to file based gauge data. Special plug-in modules have been developed to support proprietary data formats as provided by some complex gauges. One of the key concepts is to access existing data storage rather than copying and using duplicated data. While this may have a small impact on network load, the key benefit is the avoidance of a data management project (capacity, backup, etc.) and the duplication of data with consequences such as potential inconsistencies etc. Nevertheless, for performance reasons, aggregates can be cached. The resulting synchronized, mapped data layer is called metals object model (MOM, **figure 2**).

The unified coil data is used to calculate decisions using the rules applicable to a particular coil during a particular process step. The QualityMonitor is showing all relevant data and all rule results on a single screen. Operators can of course overrule the result and add comments. Hence, consulting a multitude of different sources (terminals, screens, printouts) is no longer required. Besides the result per coil, the QualityMonitor also creates the printed documentation – the quality certificate.

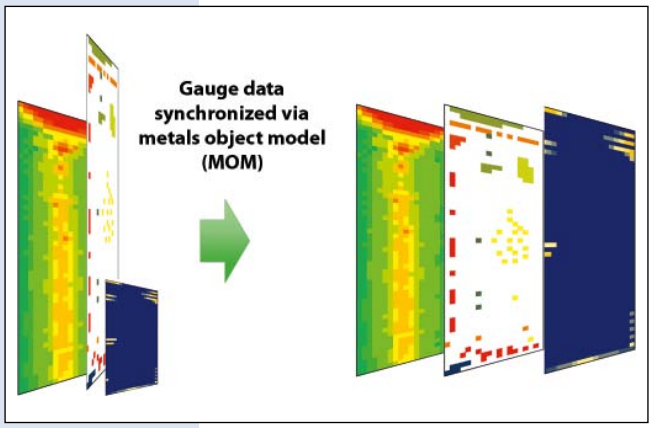

Figure 2.
Metals object model (MOM)

To configure the QES, the quality management team needs to specify the rules that are used to qualify the coils. The quality management team usually manages quality for several process steps as indicated in **figure 3**. The QES tool to manage rules and rule sets is called the LogicDesigner. The LogicDesigner uses the same MOM abstraction as the QualityMonitor to simplify data usage of a multitude of gauges and other sources. The key tasks for the quality definition are:
– defining the potential rule results, called the quality index (for example: ship, verify, block, repair, scrap),
– defining the decision context hierarchy (involving for example grade or usage),

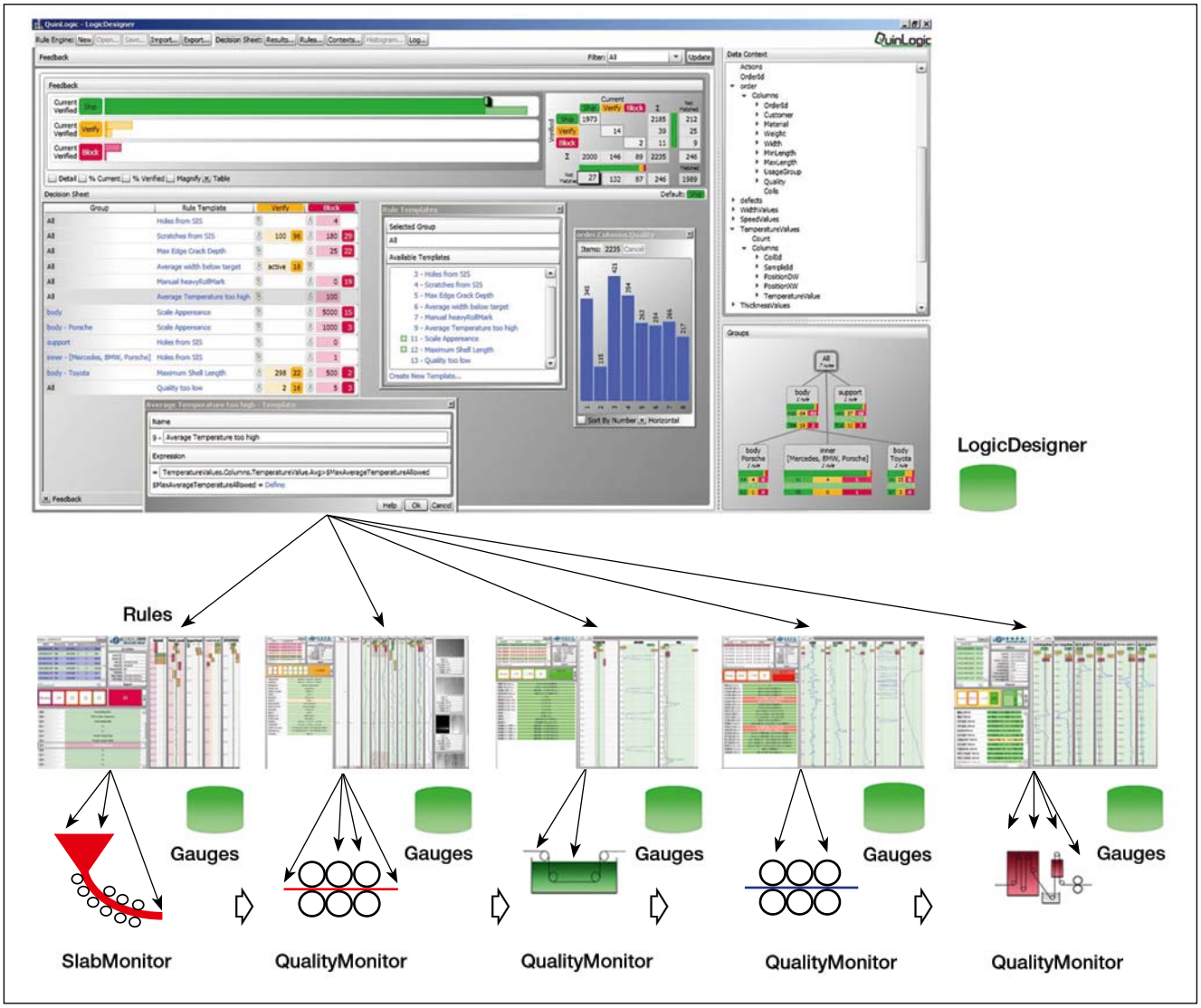

Figure 3. QES architecture with centralized quality definition via LogicDesigner

- creating and editing rules,
- assigning rules to a specific set of coils from the decision context hierarchy,
- setting the rule limits,
- testing the rule sets performance and the resulting yield.

Special attention is attached to fundamental parameters, such as the quality index, the decision context hierarchy and the resulting performance.

Quality index. While a traffic light system with "ship", "verify" and "block" is widely used, there are a lot of other index schemes possible. Shougang started with very different indexes which had been in use before. The caster index had five levels with three different review grades. The hot mill started with eight different levels, four each for automotive and non-automotive, and other lines (PLTCM, CAL, CGL1 and CGL2) started with nine levels. During the first months of intensive use, the levels have been realigned to improve overall quality management.

Decision context hierarchy. To every rule, a decision context can be assigned. If this is not done, the rule will be applied to all coils. A typical "more specialized" context may be "automotive". Rules assigned here will only be applied when the customer is an automotive customer. This decision context can be further subdivided, for example into "exposed" and "non-exposed", and "exposed" could be further subdivided by customer, e.g. to distinguish special requirement for "Ford" or "Toyota". This builds a hierarchy. For the production start of the QES, only a limited number of decision contexts were defined, ranging from 4 to 7 for the various lines. This has been much refined during the first year of intensive usage.

Resulting performance. With a defined rule set and archived production data, simulations can be performed to

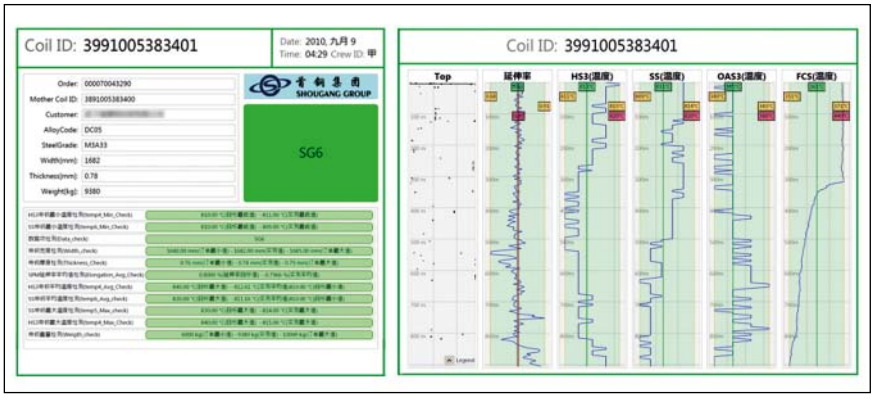

Figure 4. Shougang QES-generated quality certificate

assess the rule set performance, identify inadequate rules or rule limits and finally judge the yield resulting from this rule set. Furthermore, the rule set can be tested against another rule set or the decisions taken by quality personnel before. If the results are satisfactory, the rule set can be activated for regular production. In other cases, rules may require more changes, e.g. for limits or tolerances.

QES implementation project

The QES implementation project in total took 70 days, working in parallel at both sites, Qian'An and Shunyi. The key tasks involved in installing, commissioning and starting production were:

Process	Action	No. of rules
Casters	Disposition	~50
Hot strip mill	Grade assignment	~50
Cold rolling mill	Decision	~30
CAL	Decision	~40
Galvanizing line CGL 1	Decision	~30
Galvanizing line CGL 2	Decision	~30

Table 1. **Rules for the various processes**

- establish the IT infrastructure,
- establish data connectivity (mainly from central servers to data sources at the various lines),
- create the underlying MOM (with its XML definition scripts – this is the main commissioning activity),
- define the quality indexes (locally to the lines – because of limited project time),
- define the "decision context hierarchy" (at least rudimentarily),
- work with the quality experts to define the rules,
- implement definitions and rules using the LogicDesigner,
- tune the rule sets,
- configure the layout of screens and reports,
- train the operating personnel,
- go live (22 June 2010).

For the IT infrastructure, two fault-tolerant Intel XEON-based servers with Microsoft Server 2008 operating systems and RAID mass storage were selected. One server per site was installed as a centralized IT resource. The servers run all software instances and are used at the lines via terminal services. About 50% of the total effort was to establish the data connections and the corresponding metals object model (MOM).

Data connections were established as:
- iba databases (with process data),
- InSQL databases (with process data and tracking data),
- several MS-SQL databases (with quality assurance data),
- Oracle database (with business data for the customer target specifications),
- Oracle database (with production planning data),
- Cognex SIS (at Shunyi; with surface quality data),
- ISRA Parsytec SIS (at Qian'An; with surface quality data for the hot mill),
- Siemens-VAI SIS (at Shunyi; with surface quality data for the CAL and the CGLs),
- Siemens-VAI PLCs (with process data).

A few advanced gauges, such as a flatness gauge, were installed but not immediately connected to the MOM. This is scheduled for 2011. The integration of these gauges will be done by Shougang engineers, extending the MOM.

Rules were mostly created from specifications managed by the quality department with the exception of the caster rules **(table 1)**. Those were taken from a technology exchange with a European steel maker.

Figure 5. **QES going live in Shougang's production on June 22, 2010**

For going live, more than 200 rules were implemented. It was calculated that over one year about 500 additional rules and 50 additional decision contexts would be needed. Testing and tuning of the rule sets took three weeks to achieve good results and appropriate yields.

Localization. Significant effort was made to tune the quality certificate and the screens to adhere to Chinese standards, i.e. vertical texts, translations, etc. **(figure 4)**. All these aspects are defined with the QES in XAML layout files (using WPF technology). After some training, further modifications can now be implemented by Shougang's IT department. The entire QES finally went live at both sites, Qian'An and Shunyi, exactly as scheduled and has been continuously operating since then without failure **(figure 5)**.

QES usage at Shougang

Since the official start of the QES operations, quality certificates have been generated for every single coil at every process line. After six months, a first upgrade from release 2.0 to 2.5 of the QES was scheduled. Shougang requested a hot upgrade without disturbing the operation. This was achieved with three days of preparation. No quality certificate was missing.

A key experience during the first months was the difficulty of sustained data availability. Gauges sometimes have maintenance outages or there are connectivity failures. The QES has generally been designed to cope with such events and rules are able, for example, to generate results even in "no data" conditions. During rule updates, many details were added to rules for missing data cases. Shougang is also updating and unifying quality indexes, as has been done for all lines at Shunyi. Shougang has spent

great effort on refining the rules and has effectively tripled the number of rules.

Results

Major achievements of the Shougang QES project have been:

- very fast QA workflow, decisions can now be made online,
- very reliable performance of grading close to 100%,
- ease of use allowed a lot of new evaluation rules to be designed by the QA department,
- portability of rules ("electronic quality manual") between CGL lines and casters,
- stable 100% availability of the software, results and quality certificates.

The user group of QES has been extended to production management, team leaders and directors. Sales already uses the quality certificates to collect feedback from automotive customers about their specific needs. Premium automotive customers visited Shougang and appreciated the new QA process in place.

The QES project was finished within an extremely short time frame. Today, the overall QA process from slabs to finishing shows consistency and predictability. This was achieved with a closed loop of feedback through consecutive lines. Surface anomalies or other issues referring to variations in the casting process, can be traced back to the slab grading. Additionally, QES has created a new world of quality assurance data, which enables prioritized improvement actions based on facts rather than experience and intuition.

Major subsequent enhancements of the Shougang QES project are:

- non-stop operation even during upgrades,
- 200% increase in number of rules within one year,
- data reliability and gauge availability improvement as a consequence of QES usage,
- QES used as the source for quality planning and the corporate quality information system.

The focus is now on quality improvement, not just quality assessment.

Conclusion and outlook

The QES implementation at Shougang has for the first time scaled the QES principles to a multi-site usage level. Rules and quality certificates have proven their excellent usability. Enhancing the quality definitions is an ongoing process.

Despite previous concerns about connecting many different data sources, the MOM product approach guaranteed commissioning in a matter of weeks. Furthermore, missing data became obvious and has triggered significant improvements.

The QES is now being consistently used for all QA activities in Qian'An and Shunyi and has achieved a "missing critical" status. Furthermore, the QES has helped Shougang to attract additional customers.

Further Shougang plants are currently planning to implement the QES. On a corporate level, QES extensions, for example, towards a web based management reporting system, may be a center piece of the next level of Shougang's quality initiative. ■