Digital solutions for quality management

In today's complex steel production environment, quality engineers and production managers face increasing challenges. The demand for high-performance steel products, stringent customer requirements, and the need for cost efficiency and predictive maintenance have driven the adoption of digital tools. By Maxime **Monnoyer**[1], **Raphaël Walger**[2] and **Michele Manaresi**[3]

FIVES, an industrial engineering group, has developed an intelligent quality management system to enhance real-time quality control. The system has been successfully installed on a continuous galvanizing line at Marcegaglia Ravenna, in Italy. This article outlines the project and its results.

Eyeron®, an intelligent quality management system, enables steelmakers to compare process ranges, customer requirements, line signals, and measured product properties (such as chemical composition, mechanical properties, and surface defects) in real time (**Fig.1**). The system raises alarms in case of process or product deviations and automatically qualifies products according to the best practices immediately after production. Based on this grading, it provides recommendations for product repair or final order reallocation.

The system also provides precise and reliable product legacy follow-up, which enables comparisons between upstream and downstream signals and/or defect maps. These capabilities allow for automatic defect prediction, defect root cause analysis, and process-drift analysis based on powerful AI models.

Other features, which can be fully customized, include an SPC module, an automatic reporting function that provides quality KPIs and production summary, and a web-based application.

Case Study: Eyeron® at Marcegaglia Ravenna

Marcegaglia Ravenna, located in Italy, has chosen this digital solution due to the plant's wide variety of incoming coils and a multitude of end-customer requirements, which made manual quality control management challenging.

The project consisted of several phases. The pilot phase started in 2023 on the plant's continuous galvanizing line (CGL Nº4) to align with customer quality expectations. Specific features were implemented (**Fig.2**), including:

- Data collection from a process data acquisition (PDA) system, manufacturing execution system (MES), and surface inspection system Parsytec (SIS). The injector programme (ETL) transforms the data for each coil into a readable software file
- Installation of the Eyeron® software and database (data warehouse)
- Rule configuration to generate a grading score based on five criteria: process parameters, product parameters, surface quality, chemical composition, and mechanical properties
- Development of specific functions, including the Marcegaglia Surface Quality Index (MSQI) and real-time process alarms

Software functionalities

To illustrate the capabilities of the quality management software, the following images highlight its key functions and user interface components.

The product page (**Fig. 3**) lists the different coils produced on CGL Nº4 and is sorted by date. It provides main product information such as ID, steel grade, size, and the automatic grading result, considering the global and detailed grading score for the criteria group. From this page, users can filter products by characteristics, signal levels, grading results, etc. When the system is connected to more than one process, the user can also navigate between them to access specific production results.

The individual product page with signals display (**Fig. 4**) shows detailed information when a user clicks on a specific product. All signals related to the product can be displayed based on the product's length. Upstream (when available) and downstream

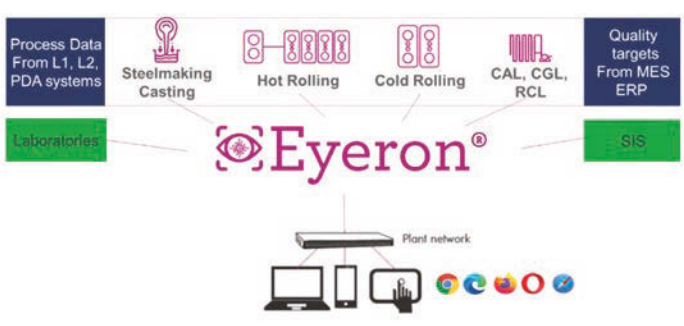

Fig 1. Eyeron® data collection and display architecture

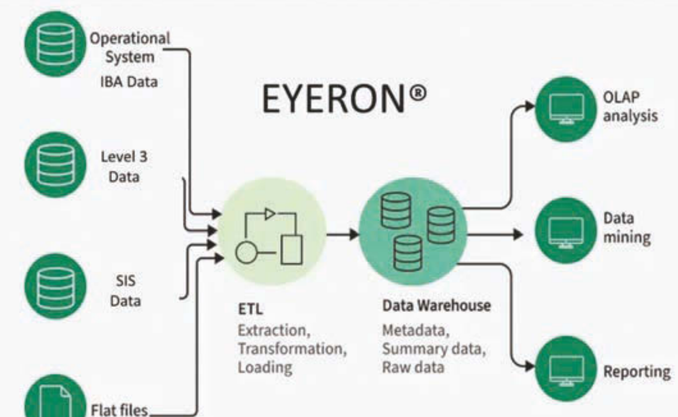

Fig 2. Eyeron® architecture at Marcegaglia

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Fig 3. Product page

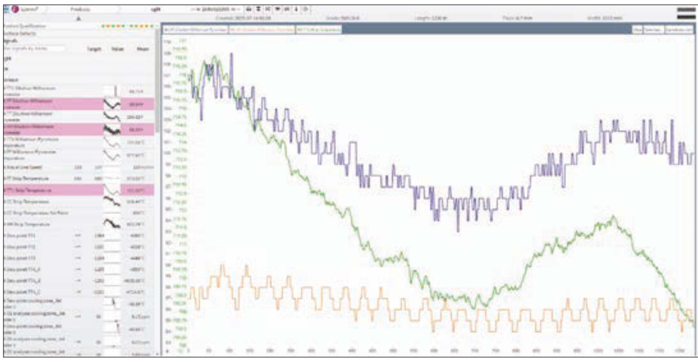

Fig 4. Coil temperatures are shown on the individual product page

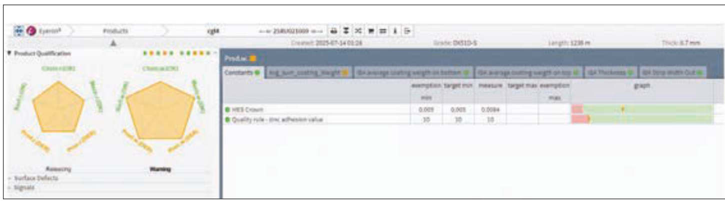

Fig 5. Standard coil grading (with tolerances per product's length) for fixed signal

signals can be viewed together with automatic elongation and consideration of cuts, scrapping, head-tile inversion, and more. Users can also access specific data such as mechanical properties, chemical analysis, product defect maps, and qualification results.

Standard coil grading illustrates the quality grading results for a given product. On the left, the five grading criteria are displayed in a user-friendly way, and the global grading results are indicated by colour (two grading levels are defined, for warning at first and then for final release). In this case, orange indicates that the coil needs to be checked. The grading results for fixed signals are shown in the diagram (**Fig. 5**) on the right, while variable signals are shown in **Fig. 6**. Tolerances are indicated by a colour code: green for qualification, orange for derogation, and red for non-qualification. Different tolerances can be defined in the grading rules based on position along the product's length.

Marcegaglia surface quality index (MSQI)

For this project, Fives and Marcegaglia developed a dedicated index called the Marcegaglia Surface Quality Index (MSQI). The MSQI provides a graphical representation of the evolution of the global surface quality over the coil length based on a continuous signal. This representation can be used for precise product quality grading. The MSQI is calculated according to the following formula for each metre length and can be filtered by individual defect class or by a group of defects:

$$MSQI = \frac{\sum_{i=1}^{n} d_i I_i^G I_i^D I_i^P I_i^F}{Width * Unit\ of\ length}$$

Where:

d_i = number of defects in each unit of length

I_i^G= Gravity index, depending on the defect class

I_i^D= Defect distribution index, depending on the standard deviation of defect position from the edge

I_i^P= Defect position index, depending on the defect distribution over the coil width

I_i^F= Face index, depending on the quantity of defects on each product side

Fig. 7 shows the evolution of MSQI for a given product with the different thresholds: qualification, derogation, and non-qualification. According to the signal, the product shown in the example will not be qualified.

Fig. 8 represents the superimposition of a defect map and the corresponding MSQI signal evolution, as well as the strip temperature signal. Superimposing defect maps, MSQI signal, and process signals can be useful for investigating defect root causes.

Real-time process alarms

Fig. 9 shows that generating real-time process alarms allows operators to correct quality deviations as soon as they appear. This increases the number of first-time, first-choice coils.

Results

The Eyeron® pilot programme at Marcegaglia Ravenna has produced

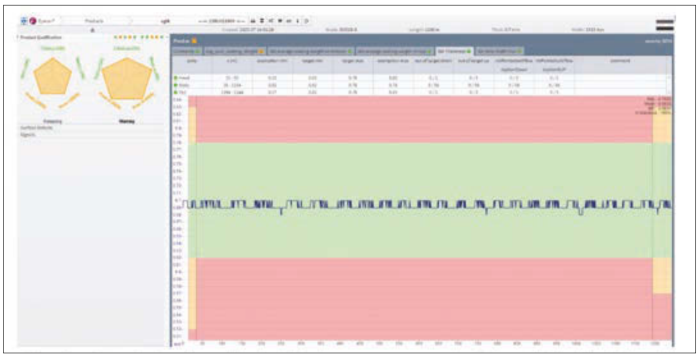

Fig 6. Standard coil grading (with tolerances per product's length) for fixed signal

Fig 7. MSQI signal example

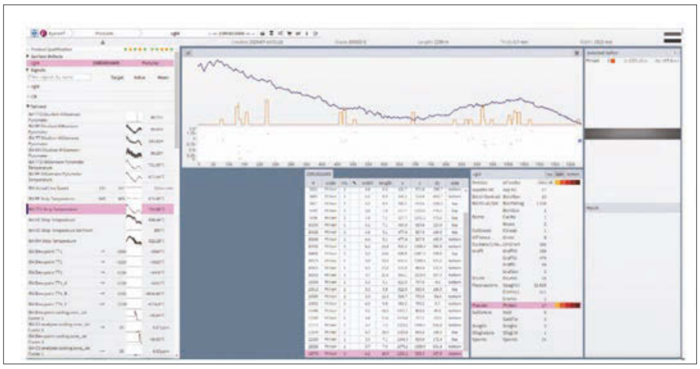

Fig 8. Defect map with superimposed signals (MSQI and strip temperature)

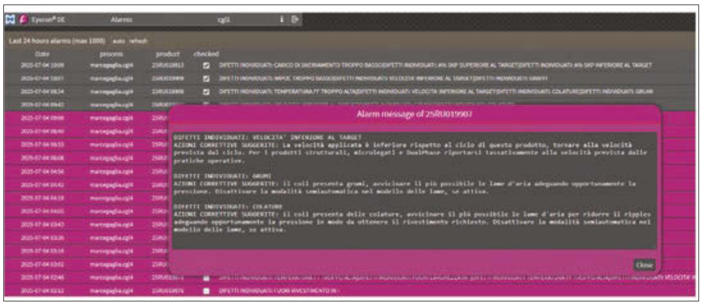

Fig 9. Defect map with superimposed signals (MSQI and strip temperature)

measurable improvements:

- *Improved process efficiency:* 29% reduction in suspended coils after 12 months at the exit of CGL N°4
- *Enhanced quality control:* significant increase in the reliability of quality control across all product characteristics
- *Process monitoring:* improved process reliability by continuously evaluating key parameters to maintain optimal performance and compliance
- *Proactive alerts:* early deviation detection to prevent non-conformities
- *Corrective guidance:* suggestions for corrective actions to resolve issues
- *Reduced non-conformities and disputes:* fewer internal non-conformities and disputes

The project is now advancing to its second phase, which aims to expand the system to cover the entire cold rolling plant, including three CGLs, a skin pass mill, three cold rolling mills, and two pickling lines. This will also include operator training for broader adoption, development of a real-time dashboard for production monitoring, and advanced failure analysis using machine learning.

Implementation of the intelligent quality control system atplant level has demonstrated clear benefits in quality control, process monitoring, and operational reliability.

The upcoming expansion marks a significant step toward full digital integration of the cold rolling plant, enabling comprehensive quality management and real-time process optimization across multiple production lines. ■