STATE OF THE ART PRODUCT QUALITY MANAGEMENT – OPERATIONAL SUCCESS WITH STATE OF THE ART PRODUCT QUALITY ANALYSIS (PQA) SOLUTIONS*

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Abstract
Driven by customers, especially from the automotive sector, the supply of 100% prime quality has become essential. Furthermore the implication of quality costs and the yield of first class products define the steel companies' profitability and overall success significantly. The SMS group together with its subsidiary MET/Con has developed a comprehensive solution to assess the product quality over the production and processing chain. Process and production parameters originating from various data sources of the process automation are examined on their impact of quality related characteristics.Expert know how and comprehensive operational experience is translated into a quality guideline and a regulation framework as the sensitive core of the PQA solution.Once implemented, the system identifies immediately steel grade specific, deviations from ideal standard and proposes corrective actions including a final evaluation for each product at each processing step.The X-Pact® PQA (Product Quality Assessment) system is a substantial tool for root cause quality analysis and provides the required support to the production team. It will become an integral part of the corporate quality management system.
Keywords: Product quality management; Quality assessment; Metallurgical know how; Process conditions; Operation control; Digitilisation; Production monitoring; Quality decision algorithm; AHSS multiphase steel grades.

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1 INTRODUCTION

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The SMS group together with its subsidiary MET/Con has developed a comprehensive solution to assess the product quality over the production and processing chain. Process and production parameters originating from various data sources of the process automation are examined on their impact of quality related characteristics.

Expert know how and comprehensive operational experience is translated into a quality guideline and a regulation framework as the sensitive core of the PQA solution. Once implemented, the system identifies immediately steel grade specific, deviations from ideal standard and proposes corrective actions including a final evaluation for each product at each processing step.

The PQA (Product Quality Analyser and Advisor) system is a substantial tool for root cause quality analysis and provides the required support to the production team. It will become an integral part of the corporate quality management system.

2 MOTIVATION

Global competition forces the steel companies to satisfy their customers with state of the art steel grades, premium product quality, and timely delivery taking competitive pricing into consideration. The remaining margin depends very much on the premium a supplier can realize for special/premium products and services providing additional value to the customer. Taking into consideration that the value contribution from scrap/raw material basket (iron ore, coal) to processed galvanized steel is around 100% (**figure 1**), it is obvious that the identification of deficiencies in the process, which will or can lead to quality constraints becomes more and more important. The earlier a critical deviation can be observed the better countermeasures can be executed in the following processes. In this regard the PQA system is supporting the idea of dynamic processing by considering qualitative short comings of the material in earlier processing stages by correcting them in later process steps, if considered to be feasible. This decision will be made by the PQA software based on its inherent experience and metallurgical, operational and qualitative know how.

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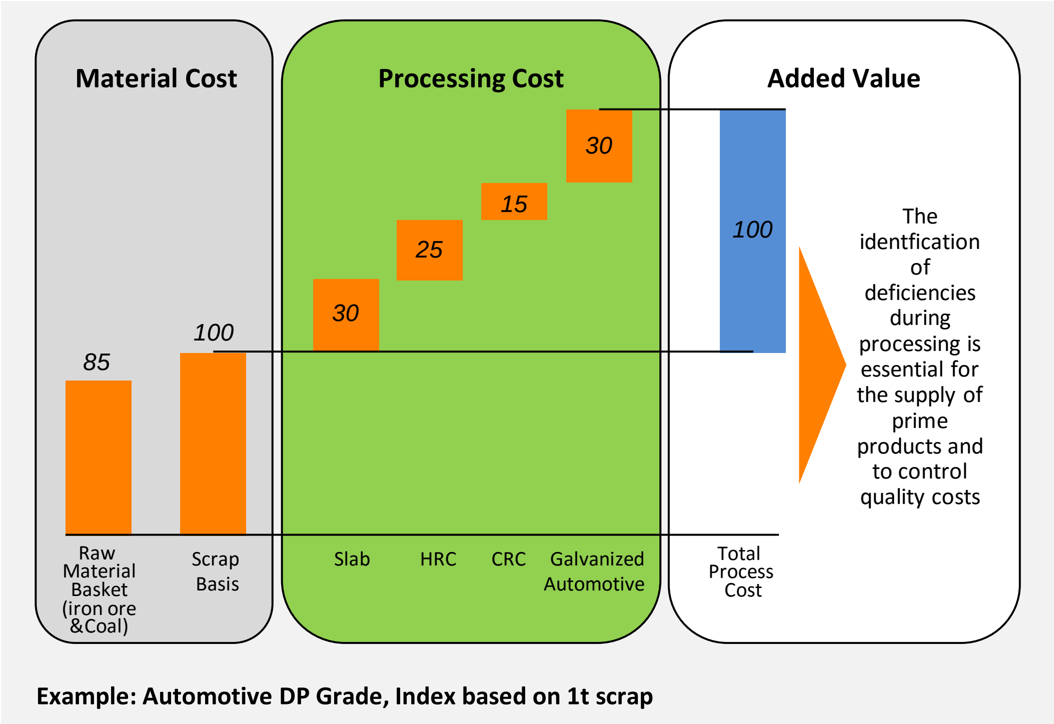

Figure 1: Value Contribution in Steelmaking

3 OBJECTIVES OF PLANT WIDE PRODUCT QUALITY SYSTEM

Driven by market developments towards increasing demand for high end products in new market segments for advanced applications (surface quality and mechanical properties) customers are requiring for a holistic integrated support in quality optimization and management. MET/Con, a subsidiary of the SMS group, developed and engineered a plant wide product quality assessment system. The integrated solution called PQA covers the essential quality aspects of the complete process chain from steelmaking, via hot rolling, cold rolling to final processing. The main and essential quality aspects are covered and converted into an integrated software solution. The highlights are the following topics:

- Visualization of plant and process conditions related to product quality
- Monitoring of product quality data and interrelations to plant and process status
- Implementation of control actions into automation control loops
- Feedback strategies for operators
- Re-assignment of defective material as an option

In general, the PQA collects, analyses, verifies and distributes quality and process relevant information from and to connected automation systems, to operators, process and quality engineers, as illustrated in **figure 2**.
Comprehensive know how and years long experience is applied to define “steel maker´s rules” to support quality decisions. Three kinds of general standards are analyzed:

- the hard rule
- the logical rule
- the contextual rule.

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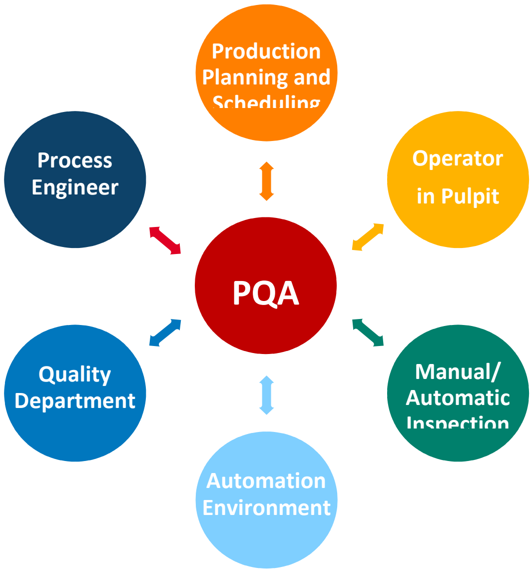

Figure 2: Communication partners and points of interaction [1]

The hard rule type 1 compares specified and achieved production and process parameter which are important properties of the material. They are analyzed, whether they are in specified limits similar to the auto blocking rules, which are already common at continuous processing lines. This includes the logic of taking not only simple deviations into account but also judging the frequency, number of deviations in a sequence and their positions.
Typical process information are product geometry, chemical analysis, temperatures and other process data (process pressure, retention time) as well as results from mechanical testing procedures including visual inspection by the operator.
The hard rule type 2 refers to detected surface defects for automated inspection systems. Based on the reliability of the defect classification it will be possible to put material on hold due to the sheer number of certain defects or their position.
The logical rules take dimensional and physical relevance into consideration. By knowing the options and capabilities of the following processes to correct non-conformities the production of non-prime material is prevented already at an early stage and as a consequence it can improve the yield of prime material output.
Figure 3 gives an example how operational know how and experience can help to correct quality non-conformities at later process steps for instance by cutting off deviations before the next process step, such as thickness deviations at the end of the coil.

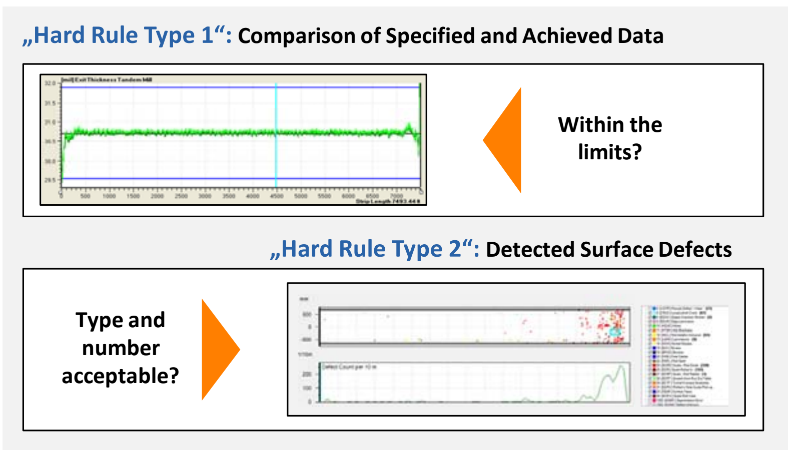

Figure 3: Quality Decision Support based on "Hard Rules"

Contextual rules refer to operational experiences and metallurgical know how when evaluating quality related events. Knowing the potentials and limitations of processes and the contextual relationship between certain quality influencing events, rules can be set up which already predict short comings of the final product in real time before the measurement of the final corresponding parameter is made in the last process step or in the laboratory.
As an example in the following table the methodology for the rules structure is shown for one specific steel group for one specific process step.

ULC / IF / steel grades, steel group 201 - 299

No	Process	Rule definition	Data interface	Process data acc. to interface list	Unit	Exceeded limit	Conditioning Actions Definitions	Influence to Quality C / I / S	Status	Reference Document	Affected downstream process
1	Hot metal Des-plant	Non De-suf hot metal	Desuf_S_content_hot_metall	Desuf content before start blowing	wt% S	> 0,015%S	Additional time for secondary desulfurization at LF, increase CaO amount	Inner quality	Not valid for deep drawing application	duty book – steelplant chapter 3.1	Advice to Quality Department
2	BOF tap	EMF O free	BOF_EMF_measurement_O_free	EMF_O_free	ppm	Ofree > 1050 ppm	Scarfing – code 2 Check Al level at LF final sample	Cleanliness	On hold	duty book – steelplant chapter 3.2-3.3	
3	BOF tap	High amount of entrapped slag	BOF slag retain dev slag amount or manual event	Manual or slag-retaining device	kg/ t steel	Slag amount > 5 kg/t	Deslagging of the slag if possible and renew the slag Increase the amount of CaO/Al addition (60/20 kg in small portions)for slag forming at LF	Cleanliness	Not valid for deep drawing application	duty book – steelplant chapter 3,3	Advice to Quality Department
4	BOF tap	BOF tap	BOF_FeO_content_tap	PLC laboratory	FeO content too high	>FeO>22%	Increase the amount of CaO/Al addition (60/20 kg in small portions)for slag forming at LF until slag becomes green colour	cleanliness	On hold	duty book – steelplant chapter 3,4	
	RH		BOF P content actual final BOF_C_content_actual_final	P-, and C-content out of limit	wt%	C act> Ctarget P actual>Pact.	Target Analyse Level 4 – end of blowing	cleanliness	On hold		Advice to Quality department for re-scheduling/rebooking
6	BOF	Tramp elements out of range before tapping	BOF_Cu_content_actual_final, BoF_Cr_content_actual_final BOF_Ni_content_actual_final BOF_Sn_content_actual_final	Cu-, and Sn-content exceeded	wt%	Cu>0.120% Sn>0,015%	Add Ni to compensate Cu/Sn – content Target: Sum 0,200% ≤ (%Cu + %Cr + %Ni + %Sn) Decrease Soaking furnace temp. at HSM	Cleanliness Surface quality (edge defects)	On hold	duty book – steelplant chapter 3.7.2	Advice to HSM (furnace adjustment
7	RH	Ladle non-clean	LF_id_non_clean	Manual event	—	—	——	cleanliness		duty book – steelplant chapter 3.5	
8	RH	Tramp elements out of range	LF_Cu_content_actual_final, LF_Cr_content_actual_final LF_Ni_content_actual_final LF_Sn_content_actual_final	Cu-, and Sn-content exceeded	wt%	Cu>0.120% Sn>0,015%	Add Ni to compensate Cu/Sn – content Target: Sum 0,200% ≤ (%Cu + %Cr + %Ni + %Sn) Decrease Soaking furnace temp. at HSM	Cleanliness Surface quality (edge defects)	On hold	duty book – steelplant chapter 3.7.2	Advice to HSM (furnace adjustment
9	RH	Much entrapped slag/bad slag condition	RH_much/bad_slag_cond	Manual event	—	—	Add CaO/Al (60/20 kg) in small portions	Cleanliness	On hold	duty book – steelplant chapter 3,6	
10	RH	Vacuum pressure low	RH_vacuum_pressure_low	Pressure inside vessel min	mbar	> 5	Check the final C – content after vacuum treatment	Cleanliness Inner quality	On hold	duty book – steelplant chapter 3.6	
11	RH	Ti level not in relation to C+N	RH Ti content actual final RH_C_content_actual-final RH N content actual final RH S content actual final	Ti /C /N /S content actual_final			Check the C/N relation %Ti = (4x%C + 3,42 x%N + 1,5 x %S)	Cleanliness	On hold	duty book – steelplant chapter 3.7.2	
12	RH	C content out limit	RH_C_content_actual_final C_target_final	C actual content	wt%	ΔC >0,005	If C actual content exceed the C target content advice to quality department	Surface Quality	On hold	duty book – steelplant chapter 5.2.2	Advice to quality department
13	RH	Si content out of limit	RH_Si_content_actual_final Level 4_Mn_content_Target	Si_actual_contal_final	wt%	> 0,06%	Pay attention for dip coating processing	Surface Quality	On hold	duty book – steelplant chapter 3.7.2	Advice to HSM (descaling) and dip coating
14	RH	Nb content out of limit	RH_Nb_content_actual_fina Level 4_Mn_content_target	Nb_actual_content_final	wt%	> 0,06%					
14	RH	Al insol > 20 ppm	RH_Altot_content_actual_final RH_Alsol_content_actual_final	Altot actual – Alsol actual = Al insoluble	ppm	> 25 ppm	Increase calm time + 5- 10 min if possible	Cleanliness	On hold	duty book – steelplant chapter 3.2-3.3	
15	RH	N level out of limit	Level 4_N_target_max RH_N_content_actual_final	N_actual_final N_target_level 4.	ppm		If N actual content exceed the N target content advice to quality department	Cleanliness	On hold		
16	RH	Calm time	RH treatment end CCM_id_slide_gate_open	Time end RH→CCM start time	min	< 25 min	Target calm time ≥ 35 min	Cleanliness	On hold	duty book – steelplant chapter 3.6	

Figure 4: Example for PQA rules for one specific steel group

Taking all gathered quality related process information into consideration including specific process events a quality decision support base is provided.
One strategic core component of the PQA solution is the linking of different information and data to each other by comparing them with actual process data and observation. With reference to the requirements of the TS16949 in chapter 4.1 which is the basis for automotive production in terms of quality supervision and process monitoring, PQA monitors, analyses and compares process data with specifications and defines actions to meet the requirements by using metallurgical and operational experience in actual context.
PQA will be include specific and customized input data:

- product standards, e.g. DIN, EN, ISO, ASTM et al.
- specific customer specifications: e.g. Mercedes, Toyota, Ford, GM, Exxon, Petrobras
- end use and final application
- metallurgical and operational experience

Every decision of the PQA is an individual one which is based on the information which is given by interfaces from order information, specifications and standards compared with actual process parameter evaluated and prioritized with contextual metallurgical experience and engineering know how like depicted by the screenshot of **figure 5 and 6**. These features make this system an indispensable tool for the successful operation of modern state-of-the-art steel plants.

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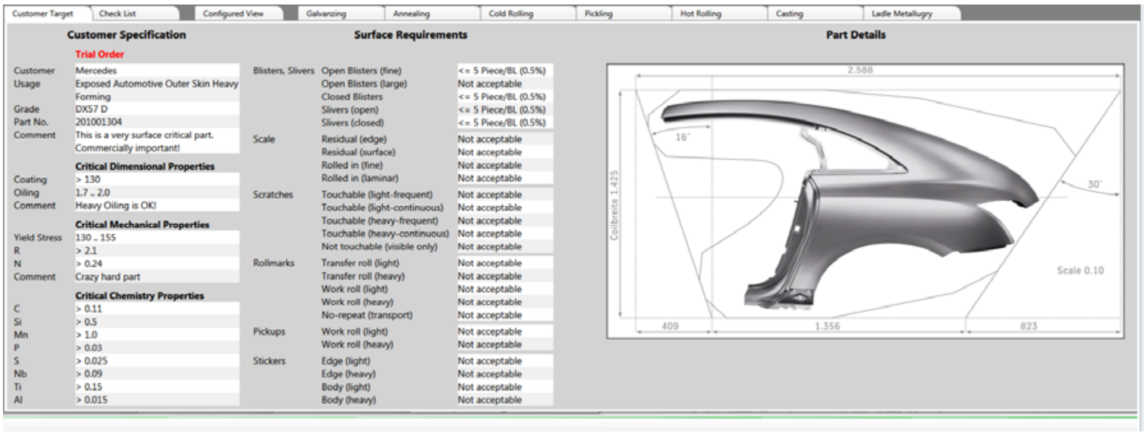

Figure 5: Example of quality information interface: rules and standards

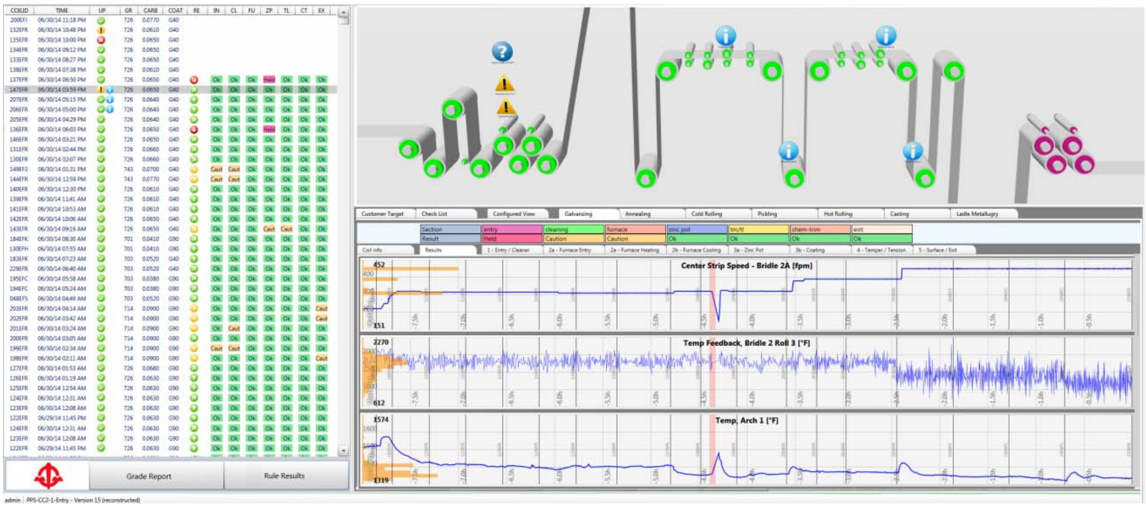

Figure 6: Example of quality information interface: process

4 OPERATIONAL STABILITY AND EXCELLENCE

A PQA solution will become the central tool for product quality analytics and assurance focusing on:

- Stabilizing operational performance
- Improving overall quality management
- Increasing transparency and visibility of quality standards and work on quality optimization
- Enhanced confidence in quality decisions
- Higher stability of operational processes
- Integration of continuous improvement by flexible rule adaption

Following economic advantages and benefits are provided to the operator and user:

- Reduced quality costs by reduction of claim rate and improved delivery performance
- Higher yield of production
- Less rework activities
- Less quality evaluation work by quicker decision making
- Faster quality evaluation and creation of statistics.

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5 IMPLEMENTATION AND CONFIGURATION

Different steel producers globally have realized the necessity for total quality management. Product quality assessment software solutions are implemented at major plants in US, Europe and China including ArcelorMittal, NLMK, Thyssen. Actually a software package is under implementation at major flat producers in China (BENXI, SHADONG) and at the latest and the most modern steel plant in the US, configured as a CSP Mini Mill, at BIG RIVER STEEL.
Customers have calculated and examined ROI´s of less than one year, while reducing drastically their quality costs, minimizing scrap and rework and maximizing prime yield. Customer satisfaction is improved in general.
The hardware, which is required comprises a powerfull and reliable dual server configuration (investment app. 50 000 USD) with 256 GByte RAM and 60 TByte data storage capacity. Depending on the customers IT strategy, the long run archiving of production, quality and process data is provided by centralized IT systems or cloud solutions.

6 CONCLUSION

The PQA has been developed and is implemented in different plants as a quality decision support solution. Based on online process event assessment an early identification of “unsuitable” material can be achieved. The software package provides a real time comprehensive product preview. The system tracks the material over the complete process chain and provides all sensitive coil data at a glance. PQA will be utilized for statistical process and quality evaluations and provides a long term data storage. User benefits are: Reliable quality, yield increase, cost reduction and satisfied customers.

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