La Metallurgia Italiana
International Journal of the Italian Association for Metallurgy

Sophisticated and advanced plant and process technologies in steel and non-ferrous rolling mills

edited by: M. Degner, M. Breuer, A. Sprock, C. Hassel, O. Jepsen, M. Quoika, A. Bregante

Key factors in the effective operation of rolling mills, now and over recent years in particular, are yield, economy, and sustainability. This applies not only to the erection of new rolling plants but also to the modernization and modification of existing mills. By illustrating some examples of projects completed by SMS group GmbH in the past few years, this paper demonstrates the highly advanced tools used to ensure a smooth ramp up that take sustainability and resource efficiency into consideration while minimizing the CAPEX and OPEX. Nowadays, such tools include methods of process and plant documentation, such as Thoroughgoing Quality Control as well as the latest measuring and control techniques and knowledge regarding material and deformation behaviors. The transfer of experience and knowledge between the customer and seller is essential for solving the tremendous challenges posed by these tasks.

KEYWORDS: MEASURING AND CONTROL TECHNIQUES, STEEL ROLLING MILL, NON FERROUS ROLLING, THOROUGHGOING QUALITY CONTROL, CAPEX AND OPEX FIGURES, EDUCATION

INTRODUCTION

The current economic situation in the steel producing industry is characterized by high overcapacity worldwide. One major reason for this is steel overcapacity in China and the lower demand for steel in sectors such as shipbuilding, thermal power plants, infrastructure, and the automotive industry [1]. There were two exceptional growth periods, one after the Second World War and one described as the Chinese steel boom starting in the late 1990s. However, the higher volume of exports compared to imports, especially in China, led to a downturn, Fig. 1. Looking at the market in detail, the side effects of this are obvious: a return to economic growth during the COVID-19 pandemic. Today in 2022, the Ukraine war in Europe and the Taiwan crisis in Asia are fragmenting the world with rapid increases in food and gas prices, among other things.

Michael Degner, Michael Breuer, August Sprock, Christoph Hassel, Olaf Jepsen, Alberto Bregante
Martina Quoika
SMS Group GmbH, Germany

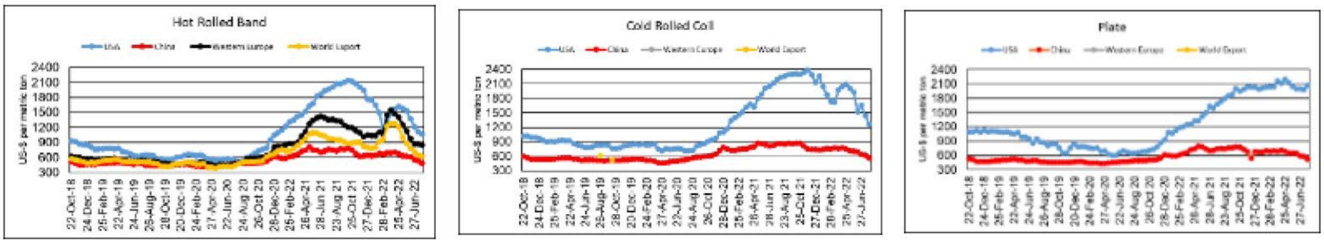

Fig. 1 - Steel price development between Oct 2018 and Jul 2022 (Source: www.steelbenchmarker.com)

Although rolling technology has been around for a long time, there is always good reason for updating the machinery and equipment, either due to new concepts, such as quality improvements (stability, thickness, tolerances etc.), or the constant demand for cost and energy efficiency, or developments in IT technology, e.g. Industry 4.0. This paper highlights some examples of best practice in former and current SMS group activities based on research and documentation. The rules given can be transferred to non-ferrous products and mills.

PREDICTIVE PROCESS CONTROL

In the past, several digital twins of the rolling process were developed by SMS group GmbH [2]. In terms of hot rolling, important models include

- Furnace model DFC (Dynamic Furnace Control): Heating the slabs, calculating the temperature increase to ensure a uniform temperature
- Rolling mill model X-Pact® Pass Schedule Calculation (PSC): Predicting roll forces, speeds, times, and setup for the mill actuators, adaptation cycles etc.
- Cooling section model CSC (Cooling Section Control): Calculating water volumes, making adjustments to ensure the required coiling temperatures

The task of these models – located on level 2 – was primarily to predict and set up the mill actuators, roll forces and torques, speeds, cooling water volumes etc. based on physical laws and measurements, such as temperatures, in order to achieve the requisite process targets including thickness, profile, and final rolling and coiling temperatures. These models were equipped with adaptation routines to recalculate the observed process conditions as closely as possible. Together with technological control systems – located in Level 1 – the process can be controlled effectively and precisely, Fig 2, [2].

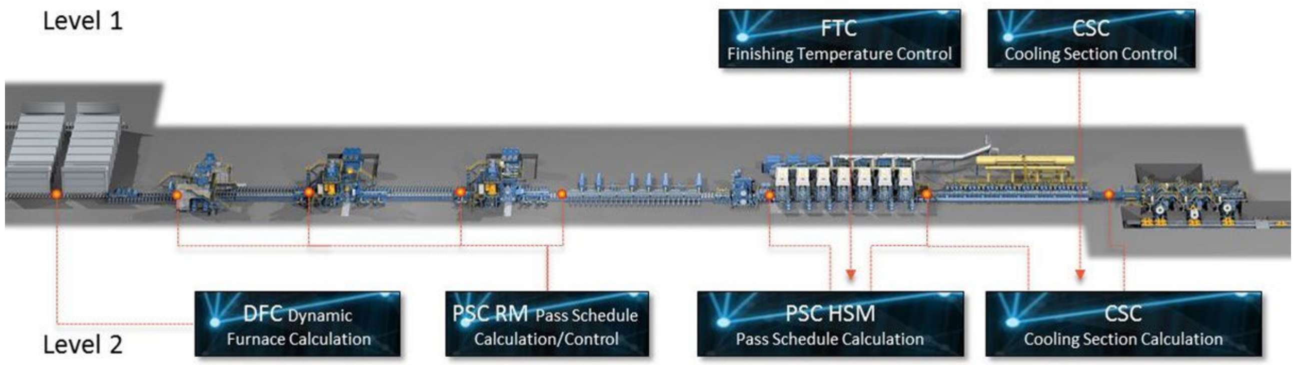

Fig.2 - Process models as digital twins in hot strip rolling [2].

With this knowledge of all the process conditions, material science models were added, Fig. 3:

- Furnace model: calculation of the segregation of alloying elements
- Rolling mill model PSC: calculation of grain sizes, recrystallization, and work hardening (micro alloyed steel), grain size development during rolling, phase transformation
- Cooling section model CSC: phase transformation, specific heats, phase composition, mechanical properties such as yield and tensile strength of final strip

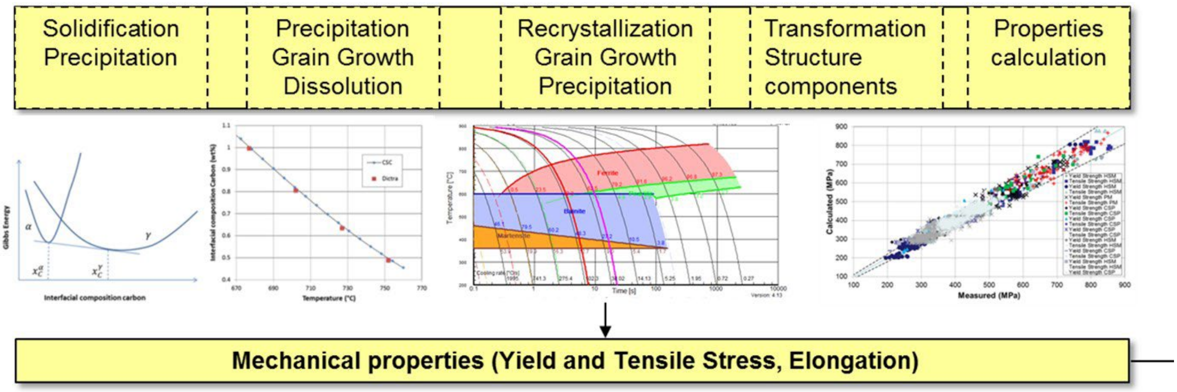

Fig.3 - Material science in process models [2].

The task of predictive process control is to retain the mechanical properties of the strip by changing the process.
The first step in developing this was to exchange important data between the different models using traditional communication methods.
Each digital twin received the necessary data from the other model.

For example, the performance of the cooling line is directly linked to the final rolling speed and the final rolling temperature of the strip. Direct communication between PSC and CSC models provides these speed-temperature data and enables the correct setup of the cooling line, Fig. 4 left. The controller of the cooling line is disburdened and has only needs to react on small process disturbances.

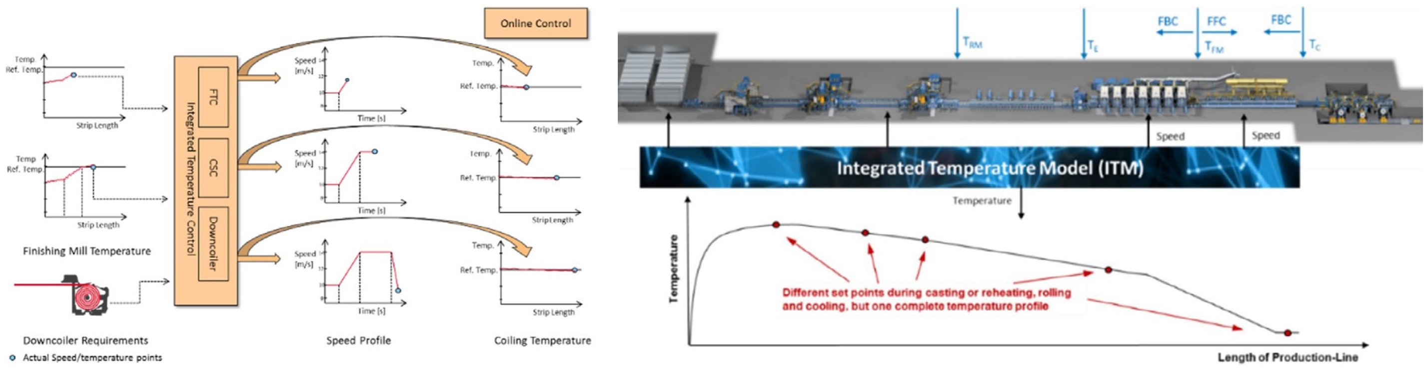

Fig.4 -Temperature control - Interaction between PSC and CSC (left) and new advanced approach with ITM (right) [2].

The second step is to establish a new optimization process covering the individual digital twins, Fig. 4 right. The goal of the system is to achieve the required mechanical properties of the strip:
- Based on an established process
- Actual changes to the process are fed back to the models and recalculated
- Changes to mechanical properties are evaluated
- Models modify the process conditions to evaluate the impact of each process step
- Predictive process control collects these data and corrects the process step(s).
- This is repeated until the target mechanical properties are achieved
- A new setup is generated for the process with modified targets for the individual process values

These changes in the process conditions also bring about changes in the process control targets. The cooling rate or final coiling temperature may differ from the original process design. A system of providing feedback to the Quality Execution System QES must be established in order to transfer the new rule parameters, Fig. 5.

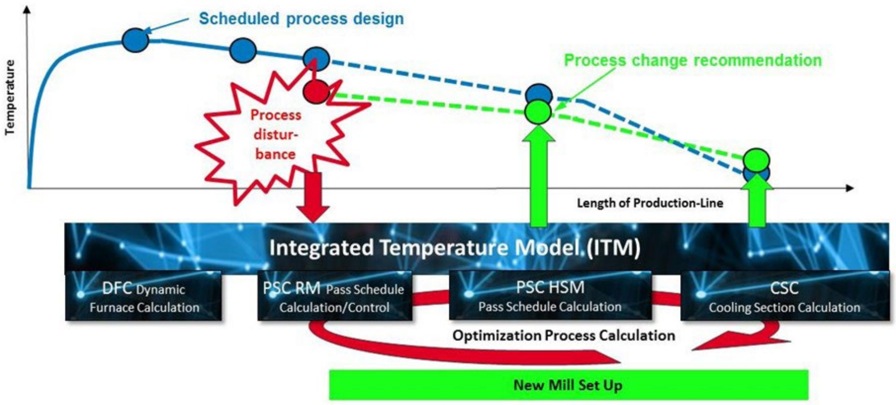

Fig.5 - Process optimization with ITM [2].

The ITM "optimizer" is designed to work out recommendations for process changes. It is an assistance system for our customers to ensure product quality and increase yield. Other objectives are conceivable:

- Production capacity maximization
- Low energy consumption
- Low water consumption
- Reduction in costs for chemical composition
- Resource savings in total

An application is reported in [3].

CUTTING EDGE TECHNOLOGY FOR HSM – STRIP STEERING CONTROL

The stability of the hot strip mill rolling process remains a major topic when it comes to processing thin and hard materials. Strip steering problems, especially at the end of rolling, and tail-out are a primary source of unscheduled down times in a hot strip mill. The main focus of the new X-Roll® Guide system is to improve mill stability and strip quality. An overview of SMS group developments in recent years with regard to equipment and control strategies is given below, Fig. 6 left [4]. The new side guiding system in the entry area of the finishing mill is introduced and explained with examples of operating practice. The system provides reproducible conditions for the threading process as well as during rolling. Steering control directly benefits the availability of the mill. New developments in roll alignment control strategies based on the roll force and mill stand entry guide force measurement [4] have improved steering control performance.

Additionally, a camera-based measuring system is introduced that generates direct process feedback on the strip position. Together with the roll alignment control, it provides the necessary control parameters for adjusting the roll gap and guiding the strip in a correctly centered position through the mill. In the area of the down coiler, the coiling stability and quality, including the optimal coil shape, is controlled with the side guides and, in the case of high-strength material in particular, with the hydraulically-driven chute roll [4].

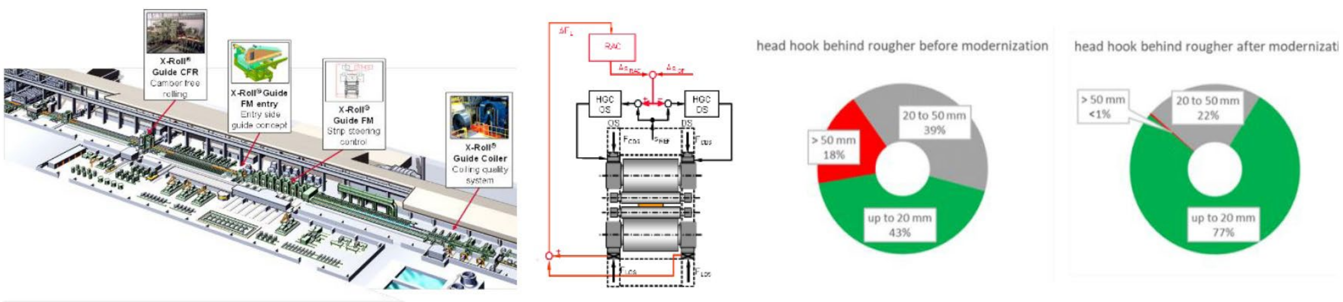

Fig.6 - Typical hot strip mill layout with strip steering systems (left) together with Roll Alignment Control (RAC) for a roughing mill stand (center) and improved transfer bar head hook (right) [4].

The new X-Roll® Guide system is the next step in digitalization aimed at achieving a fully automatic rolling process. It comprises SMS group's holistic approach to improving hot strip mill rolling stability in all relevant stages of the process.

Different systems for controlling the strip steering developed by SMS group GmbH are highlighted [4, 5].

- Roughing mill: X-Roll® Guide Camber Free Rolling CFR for rolling perfect transfer bar shapes and for reducing wedges, Fig. 6 center and Fig. 6 right
- Finishing mill entry: X-Roll® Guide FM entry; stabilizing the threading and fillet rolling process, Fig. 7
- Finishing mill area: X-Roll® Guide FM; stable threading and tail-out, reduction in torn strips and work roll damage, Fig. 8
- Down coiler area: X-Roll® Guide Coiler; straight coils with minimal telescopicity

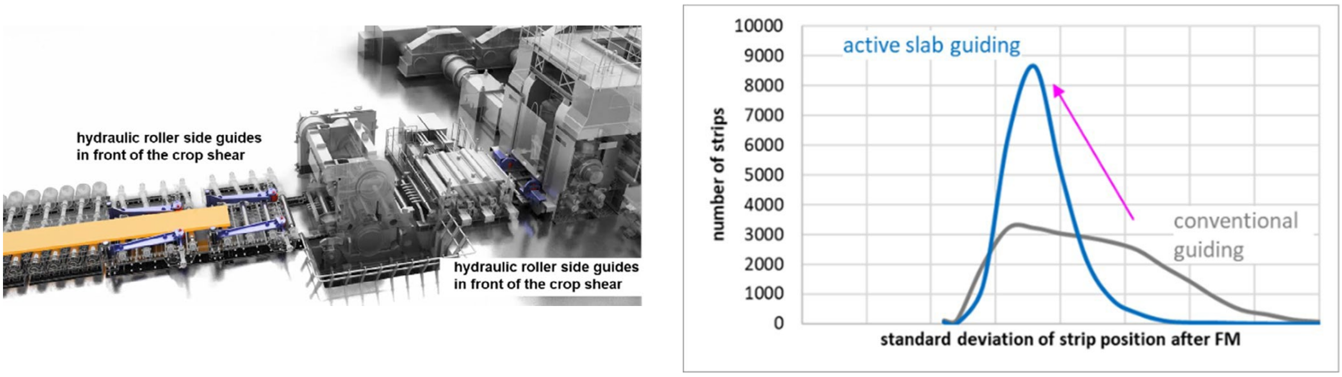

Fig.7 - Mechanical design of X-Roll® Guide FM entry [4] (left) and operational results (right) [4].

All performance modules combine reliable mechanical actuators, sensors and automation systems with adequate control loops and tracking. These mechatronic systems are controlled and adapted with corresponding measuring devices. They can be added to an existing rolling plant as a whole unit or in packages. Each module has its own advantages and helps to increase a hot strip mill's rolling stability and yield. The selection of the technology packages depends on preconditions like the product mix, mill condition, or the automation standard used. Such systems also have to show an adequate return on investment. In a hot strip mill, the investment can be justified simply by the amount of torn strips, downgraded material, and the resulting work for roll changes, unscheduled down times, and roll grinding. Additional rolling time can be used to boost production capacity. The higher the volume of thin-gauge hot strip and hard material produced, the greater the benefits of the systems.

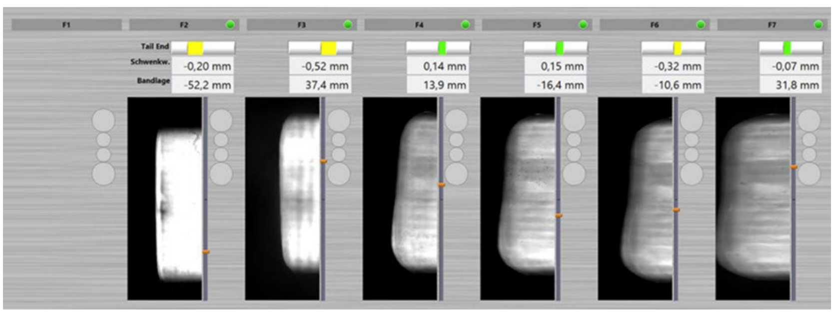

Fig.8 - Measurement results of a 7-stand hot strip mill equipped with the X-Roll® Guide System [4].

FUTURE ACTIVITIES AND CONCLUSIONS

The sophisticated hot rolling models developed in the last decades also include the development of microstructure models during rolling of the strip. Predictive process control is becoming a reality. Disturbances during the rolling process can be compensated to achieve the target strip properties or to change the target values. This avoid downgrades or additional property testing in the future. With the modules for strip steering, the operational performance of a hot strip mill can be gradually improved. Cobbles and torn strip ends can be reduced, and the coil quality and yield can be optimized. The combination of rigid and reliable equipment coupled with automation solutions creates a system that represents a huge leap forward in process control and safe rolling conditions. These systems will be developed further to meet the demanding requirements of future steel and non-ferrous products [1,6]. The next steps to be taken relate to performance optimization and connection coupling to level 3 systems, to allow fast responses in production planning and order change management.

REFERENCES

[1] Buchmayr, B.(✝), Montanuniversität Leoben, A-8700 Leoben, Austria; Degner, M., SMS group GmbH, Germany; Palkowski, H., TU Clausthal, Germany: Future challenges in the steel industry and consequences for rolling plant technologies, Proceedings ESTAD 2017, p. 61.

[2] Breuer, M. SMS group GmbH, Germany; Sprock, A., SMS group GmbH, Germany; Peretic, M., SMS group Inc. USA: Predictive Process Control – the next step to quality assurance. Report AISTECH 2019.

[3] Grybel, K., SMS group GmbH, Germany; Hassel, C. SMS group GmbH, Germany; Pronold, K. SMS group GmbH, Germany; Dickel, D., SMS group GmbH, Germany: Integrated Temperature Model for CSP® Nexus Plants for Superior Hot Strip Production. Report AISTECH 2022.

[4] Jepsen, O., SMS group GmbH, Germany ¸ Mengel, C, SMS group GmbH, Germany ¸ Breuer, M., SMS group GmbH, Germany: Cutting edge technology – Strip steering control. Report AISTECH 2022.

[5] Olaf Jepsen, Adolf Müller, Joachim Immekus, EP1896200B1, Process and device for intentionally influencing the geometry of roughed-down strips in a roughing-down stand

[6] F. Gorgels, O.N. Jepsen, P. Siemann, SMS group, Italy: X-Shape Hot - Flatness Measurement in hot rolling mills. 12th International ROLLING Conference – Trieste (Italy), 26-28 October 2022.