PERFORMANCE MODULES – A CONVENIENT WAY TO MODERNIZE HOT ROLLING MILLS*

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ABSTRACT
In order to support hot rolling mill managers in improving the utilization of their plants, SMS group offers well defined Performance Modules. These are technologies, components, automation solutions or services, which can be implemented in existing plants to increase competitiveness in categories of efficiency, productivity, quality and process and product control referred to as “Industry 4.0”. Except the Performance Modules dedicated to the last category, targeting overall process controls, Performance Modules are characterized by quantifiable benefits. Performance Modules related to hot rolling mills are e.g. camber free rolling, modular laminar strip cooling system, new edge masking and intelligent components.

Keywords: Hot strip mill (HSM); CSP®; Heavy plate mill; Performance Module ease.

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1 INTRODUCTION

The steel industry nowadays has been coping with the challenge of overcapacity and associated deterioration of steel prices. Therefore steelmakers are reluctant to erect new steel plants and further increase production capacity. Instead, operators are aiming to make existing mills more efficient by modernizations or by adding more value to the steel by improving their quality. In times of overcapacity and tough competition resulting in low steel prices only the best performers are able to make profit, whereas the low and averaging performing companies may not be able to survive in the medium term. In addition to factors like raw material sourcing, cost of labor and energy, efficiency of the production route plays a main role. Bringing the plant to the highest possible level of efficiency in terms of yield, utilization ratio, manpower requirement and energy efficiency will result in low conversion costs.

In order to support hot rolling mill managers in improving the utilization of their plants, SMS group offers well defined Performance Modules. These are technologies, components, automation solutions or services, which can be implemented in existing plants to increase competitiveness in categories of efficiency, productivity, quality and process and product control referred to as “Industry 4.0”. Except the Performance Modules dedicated to the last category, targeting overall process controls, Performance Modules are characterized by quantifiable benefits. Performance Modules related to hot rolling mills are e.g. camber free rolling, modular laminar strip cooling system, new edge masking and intelligent components.

The Performance Modules treated in the paper are presented according to material flow as follows:

(1) Newly designed slab and strip descaling systems equipped with frequency controlled pumps and maintenance friendly top and bottom header design. (2) Rigid hydraulically driven heavy side guides for centering actions enabling camber and wedge free rolling of transfer bar and final strip. (3) Heat cover hoods with individual changeable heat panel elements providing less maintenance effort and extended reliability and efficiency. (4) Torque spindles for the finishing train drives transmitting rolling torques even using smaller work roll diameters. (5) Compact Roll Cooling System based on forced convection principle. (6) Assistant system for proper leveling the finishing train stand screw actuators to prevent strip tail end chewing during feeding out causing roll and mill stand damages. (7) Reinforced and superreinforced laminar cooling headers providing higher cooling rates for processing steel grades with advanced mechanical technological properties. (8) Asymmetrical acting strip edge masking system controlled by the strip tracking behavior on the run out table protecting over cooling of the strip edges and flatness defects.

For heavy plate mills the multi flex quench system was developed fulfilling necessary cooling rates for processing plates with advanced mechanical properties for more sophisticated applications. Finally the topic Industry 4.0 applications are discussed.

2 HIGH PERFORMANCE MODULES FOR HOT STRIP MILLS

2. 1 Slab and strip descaling systems

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The challenge is the cost efficient descaling of slabs and strips on one hand side and on the other hand side the reduction of maintenance costs for descaling equipment. This can be solved by implementing latest piston pump technology with frequency controls. This results in no further requirement of high pressure accumulators. The latest valve technology guarantees high wear resistance and an optimized flow characteristic design. Together with the latest nozzle technology this gives savings in water and energy usage and consequently ensure high slab and strip descaling results. The ROI-time is less than two years due to reduction of energy costs and water consumption.

The descaling valves are maintenance-intense due to acting high pressures and cavitation especially when loaded. SMS group together with Dr. Breit GmbH from Germany developed a new descaling valve preventing damages caused by cavitation. By feed forward control of the opening and closing of the hydraulically operated valve, the impact of the pressure impulse and resulting loads on the descaling valve are minimized and will increase the life time substantially.

2.2. Rigid hydraulically driven heavy side guides and camber free rolling

Camber-free rolling makes it possible to produce strip without or minimized camber and with a wedge-free thickness profile when performed in combination with heavy, hydraulically actuated side guides in the entry and exit sides of the roughing mill and finishing mill stand. Any possible camber is detected and eliminated by the restricted guidance of the side guides and by tilting the screw-down actuators during the horizontal pass on the rougher. The material flow is perpendicular to rolling direction within the roll gap; the thickness profile will be almost wedge-free. Figure 1 on the left-hand side illustrates the principle of camber-free rolling with heavy side guides. The photograph in the middle shows a camber-free transfer bar. On the right-hand side the results of an evaluation of the camber size are illustrated for 1,000 strips, each rolled with the side guides in position and with force control mode. The force control mode of the hydraulic side guides on the rougher provides a 2-sigma value of less than 30 mm for the camber. Minimization of camber formation serves to improve the strip tracking behavior in the finishing train and on the run-out table. The cobble rate decreases and roll damage caused by bumping strips is reduced. Yield is improved and consequently a more economic production is achieved.

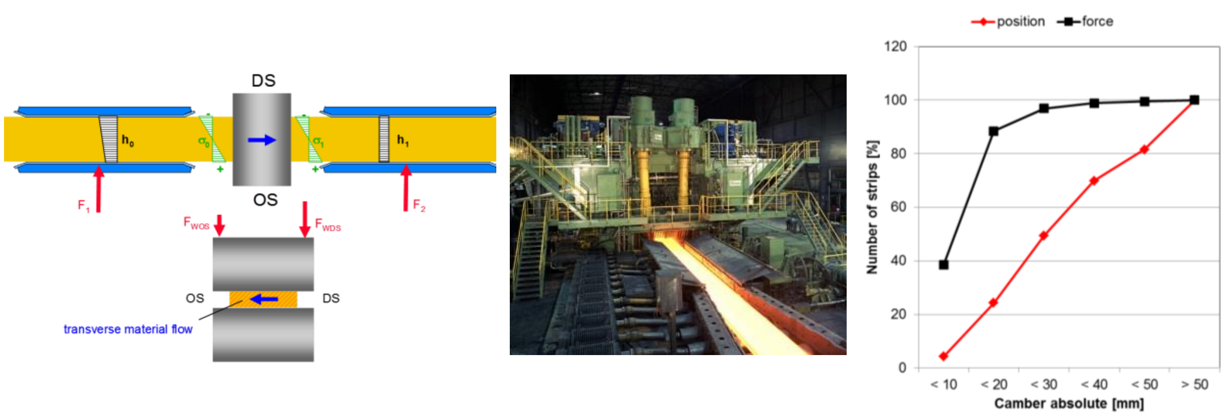

Figure 1: Camber-free rolling of hot strip – principle and application

2.3. Heat panels for heat conservation

Heat panels serve to reduce the heat radiation that causes temperature decrease along the transfer bar length. The temperature difference between transfer bar head and tail is roughly 50 % less when using heat panels as opposed to rolling without them.

Rolling behavior in the finishing train is more stable when using the panels on the delay roller table due to reduced temperature decrease along the transfer bar length. The product mix can be shifted towards smaller final thickness and/or towards higher-strength steel grades.

The heat panels are arranged as swiveling elements above the delay roller table, figure 3. This enables inspection and maintenance of the elements to be simplified. Within each panel the insulating elements are formed as individual rectangles. They are mounted on the panel and can be changed individually in case of damage, figure 2.

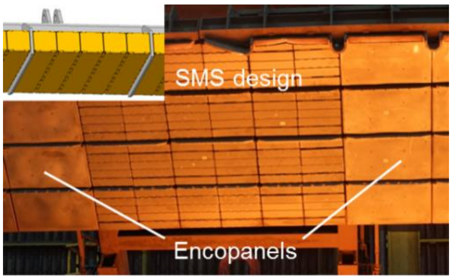

Figure 2, 3: Design(l) and arrangement of heat panels (r)

The challenges for stable operation of the heat panels between roughing mill and finishing mill are permanently heating and cooling down phases during rolling. This results in short life time of the equipment and high OPEX. The SMS solution is a new and patented design and the material of the panels resulting in higher life time of nearly 6 months, better efficiency in operational and maintenance figures with lower OPEX for replacement of 20 % to 30 % compared to others and improved temperature homogeneity over width.

2.4. Sieflex®-HT spindle for high torque transmission

With the new Sieflex®-HT gear-type self-aligning spindle it is possible to reliably transmit drive torques that are more than 50 % higher than those previously attainable. Especially in the initial stands of a finishing mill, the HT (High Torque) spindle allows the attainment of the greater rolling torques and forces that are increasingly being demanded for the production of high-strength hot strip.

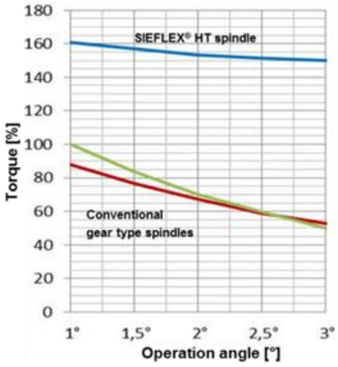

Figure 4, 5: Comparison of operation angles (l) and manufacturing if the Sieflex®-HT gear-type drive spindles in the SMS group's workshop in Hilchenbach

A spindle represents a core element when it comes to the transmission of drive power from the motor via the main- and mill-pinion gear units as well as the couplings to the work roll of a hot-strip mill finishing stand. As a consequence of the ever higher requirements involved in the production of high-strength grades, it is necessary to increase the capacity of the entire drive train. The space available for the spindles is set by the work roll diameter, which in most cases cannot and should not be enlarged. For this reason the spindle components themselves have to transmit higher drive torques. The starting point was comprehensive FEM (Finite Element Method) analyses, giving detailed information on the loads incurred in the rolling process. The design of the new HT spindle and, above all, of the gears was carried out on the basis of these findings. The geometry of the gears was optimized to the effect that in spite of heavy misalignment the loads are uniformly distributed to the gear flanks. This means that even at a misalignment of 3.5 degrees almost full torque capacity is available, figure4.

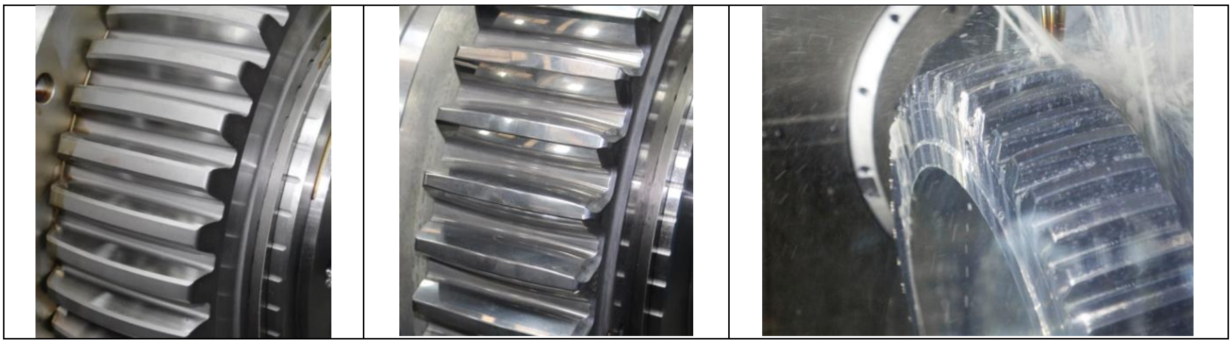

Figure 6: Sieflex®-HT gear-type spindles (center and right hand side) in comparison with conventionally manufactured spindles (l)

The Sieflex®-HT spindle is the best solution for roll drives in hot strip mill stands in case of high-strength material rolling. The new design is fatigue endurable ever in case of high loads. It is equipped with an oil circulation lubrication system providing a clean surrounding and higher spindle life spans; manual lubrication is not necessary. The Sieflex®-HT spindle is characterized by low maintenance need. Figure 6 gives on the left a spindle with conventional design, in the center a Sieflex®-HT spindle with its toothing and on the right its special manufacturing method. Monitoring of Sieflex®-HT spindle is possible using a current generator and strain gages including data storage device integrated in the spindle. This “intelligent” spindle has no cable connections to outer monitoring devices; signal transmission takes place via radio signal. The measuring equipment cannot be damaged either in case of spindle change.

Already 14 Hot Strip Mills implemented 25 Sieflex®-HT spindles for their mill drives since 2011.

2.5. Compact Roll Colling CRC for saving of energy and water use

Conventional work roll spray cooling systems are operating with pressures up to 10 bars with roughly 10,000 l/min per mill stand. Challenging are the operational costs for energy and water use as well as spare parts with the nozzles and valves.

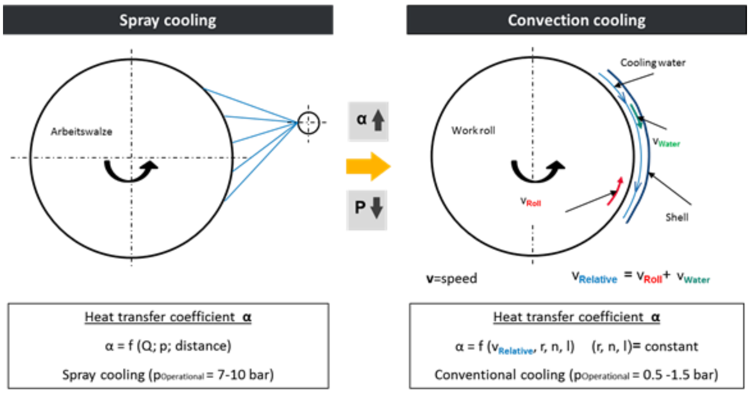

Figure 7: Spray cooling (l) and convection cooling (r)

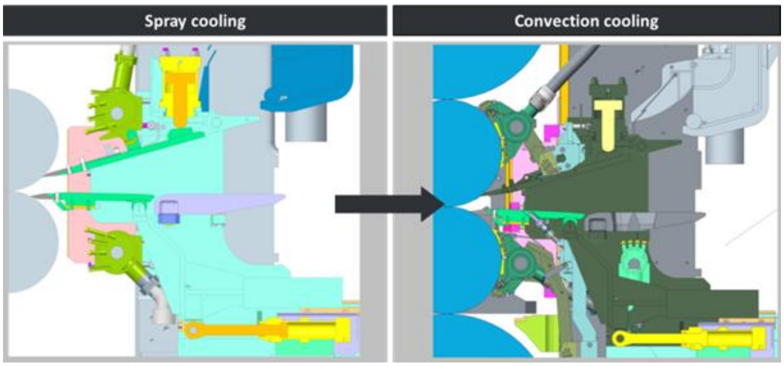

Figure 8: Layout of spray cooling (l) and convection cooling (r)

The solution for this challenge is instead of nozzle usage the formation of a water stream channel at the work roll surface to cool via forced convection principle. The work roll cooling capability is higher at same water amount compared to conventional spray cooling resulting in reduction of required pump energy. Further the guiding of water is simplified and other mill areas are nearly dry. Up to 80 % savings in energy use for the pumps are possible resulting in a reduced OPEX value of approx. 1.000.000€ per year. Further reduction of water consumption and reduction of water leakage on strip is given.

Figure 7 gives the conventional spray roll cooling and the convection roll cooling CRC by comparison. The operational pressures between 0.5 and 1.5 bars cause an cooling water flow guided by the shell against work roll rotation providing significant increase of the heat transfer coefficient. This gives an improved work cooling using less pressure, water and subsequently pumps energy.

The layout of the spray and convection roll cooling is illustrated in figure8. Whereas the distance between spray cooling nozzle and roll surface takes roughly 200 mm to 300 mm, only a very small distance of less than 10 mm between cooling shell and roll surface is possible in case of convection cooling. This fact is due to sophisticated design measures.

2.6. Assistance systems for assurance of production quality

Process observation of mill operators is essential in every rolling mill despite more and more automation functions and tools. Manual interventions for process control are necessary but dependent on operator's skills, education and knowledge. To overcome this process data can be used to generate operator assistance functions by suitable process models. Process stability and improvement of quality figures during rolling are the advantages.

An example for an assistant system for strip tail end unthreading is the Roll Alignment Control RAC. It consists of a levelling control to keep a parallel roll gap for the strip tail end to prevent tail end chewing. Further a recommendation for the next strip is given to the operators based on measurements of the differential roll forces at drive and operating side and calculation of tilting correction values visualized on the HMI on the operators pulpit, figure 9

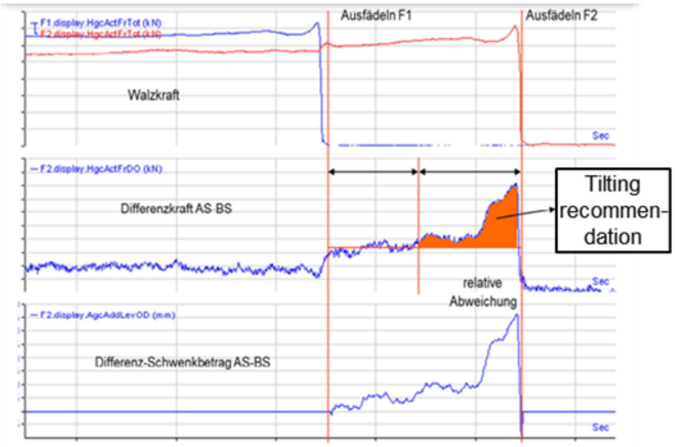

Figure 9: Roll Alignment Control – principle and recommendation for tilting

2.7. Laminar cooling for advanced steel grades with improved strip flatness

The nowadays laminar cooling with edge-masking is reinforced or super reinforced, figure 10, guaranteeing an improved cooling performance after adjustment of the following parameters: (1) Flexible cooling rates depending on the actual demand for the strip. (2) Reproducible tolerances in achieving strip intermediate temperatures and downcoiler temperatures. (3) Flexible cooling strategies, further improving material properties for application purposes, and allowing providing less use of alloying elements and therefore cost reduction.

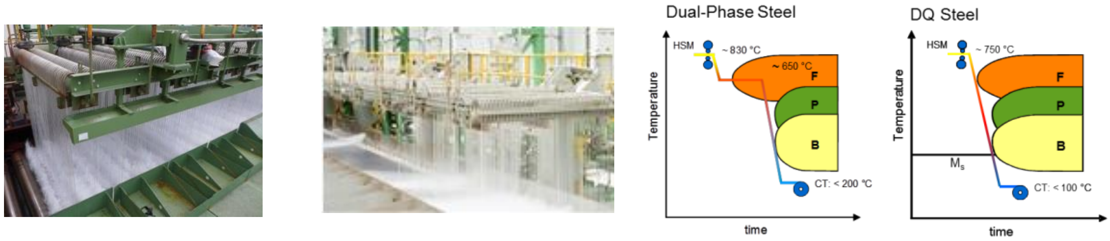

Figure 10: Super reinforced laminar cooling (l), reinforced laminar cooling in operation (c). and cooling patterns for the production of advanced DP and DQ steel grades (r)

Figure 11: Edge-masking system with asymmetrical moving masks

The edge-masking system serves for temperature homogenization at the strip edges and avoiding overcooling of strip edge areas eliminates wavy edges and improves mechanical-technological strip properties. Hot strip with improved starting conditions for downstream processes is produced. The asymmetrical operating edge-masking system is equipped with separate movable edge-masking shields, following lateral strip movement. A self-learning model is implemented for set-up calculation. Inbar control is done with automatic adjustment of the number of edge-masking systems used. The edge-masking system is a light weight construction and maintenance friendly. It is also easy to install in existing cooling sections, figure 11.

3. HIGH PERFORMANCE MODULES FOR HEAVY PLATE MILLS

Similar to conventional Hot Strip Mills and CSP® mills high performance modules for efficient plate cooling are essential to produce a final product with optimum flatness and requested mechanical technological values. This challenge can be solved by adjustable water flow covering different cooling rates and adjustable pinch roll guiding for best flatness. This new development of the SMS group is named MultiFlex-Quench® MFQ and involves the advantage that only one MFQ system has to be installed for various cooling tasks and different plate dimensions. The MFQ is an integrated solution with automation and technology. Using MFQ device gives an increase in productivity due to flexible quench rates for large variety of products. The system efficiency is proven by reduction of alloying expense up to 5 €/t due to optimized temperature control.

3.1 MultiFlex-Quench® for Acroni Plate Mill in Slovenia

The innovative MultiFlex-Quench® is characterized by its exceptionally high degree of flexibility. It sets itself apart from other quenches by the extremely wide range of cooling rates, from direct water quenching right down to gentle cooling achieved by a multiple nozzle system. As a result, flexible cooling patterns are possible for a wide range of different steel grades. The first installation is commissioned now at the steel company Acroni in Slovenia, highly specialized in plates and strips made of stainless steels, tool steels, abrasion-resistant steels and HSLA grades. The layout of the MultiFlex-Quench® is shown in figure 12; the main technical data of the Acroni Heavy Plate Mill are given in table 1.

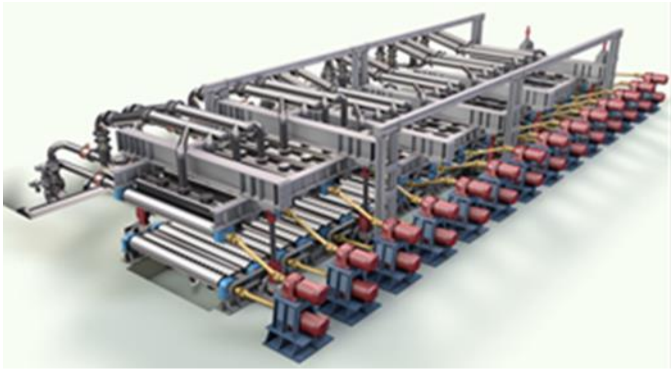

Figure 12: Edge-masking system with asymmetrical moving masks

Table 1: Acroni Heavy Plate Mill in Slovenia – Technical data

Plate width	700 mm – 2,560 mm
Plate thickness	3 mm – 100 mm
Plate length	4,000 mm – 13,000 mm
Productivity	80,000 tpy

Contrary to conventional continuous quenches, this type is no longer rigidly subdivided into an HP and an LP section. The HP section can be switched over to LP section. Therefore the entire range of cooling rates is available over the full length, figure 13 and figure 14.

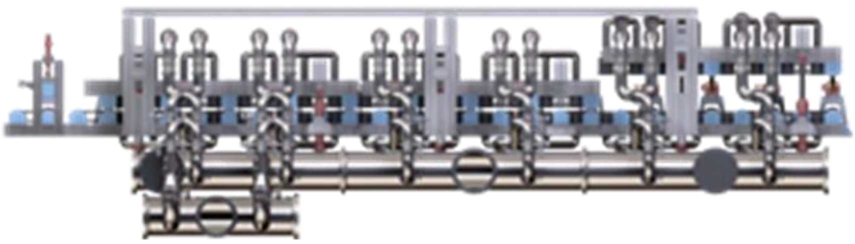

Figure 13: MultiFlex-Quench® with HP and LP section

Figure 14: MultiFlex-Quench® with extended LP section

All cooling patterns from gentle cooling to abrupt quenching can thus be realized to achieve an even wider product portfolio. By installing different nozzle systems and control valves the MultiFlex-Quench® is be individually designed to suit the product mix. Prior to commissioning of the MultiFlex-Quench®, SMS group gave assistance to Acroni in determining the optimum heat treatment parameters for new high-quality plate products. This covered, for instance, laboratory tests. Material properties such as time-temperature transformation characteristics or mechanical core values after different heat treatment steps will be integrated into the automation systems and to optimize the process parameters. Based on this know-how, it will be possible to set the mechanical properties achievable by the heat treatment more precisely, minimize the use of alloying elements, shorten process times, increase the output and hence contribute to environment protection, figure 15.

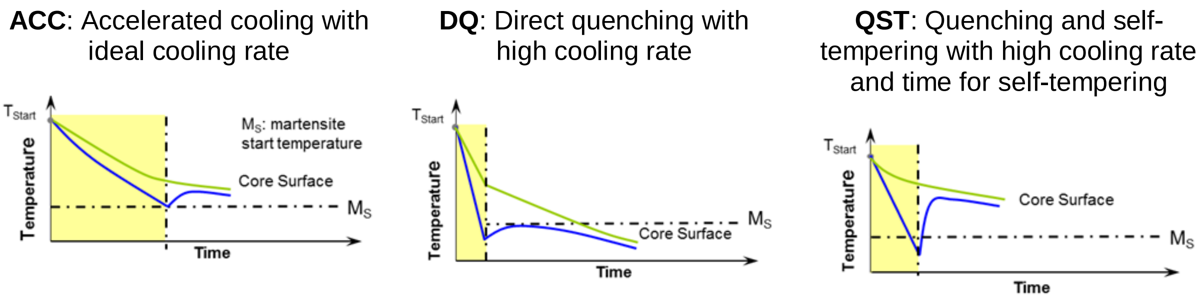

Figure 15: Different cooling technologies

Purposeful heating and cooling of plates requires holistic process control, and this is the reason why SMS group integrates its X-Pact® electrical and automation systems of the Multiflex-Quench®. To describe the complex and, in part, highly dynamic processes, mathematical models are used and combined in a holistic approach. The essential target values for plant control are set mechanical properties and respectively the microstructure, energy efficiency and plate flatness. Calculation of the cooling rates that determine the material properties is made on the basis of SMS material database which is the foundation of all SMS process models. For all steel grades it provides the most important physical and mechanical properties depending on their chemical composition and temperature. The X-Pact® cooling model then calculates the right cooling strategy for each individual plate.

4. INDUSTRY 4.0

Components and machines rolling mills and steel plants are operating as “black box” with only little operational data available. Further the life cycle status of individual components is not known preventive maintenance tasks. This challenge can be solved by applying sensors and PLCs independently on individual equipment including evaluation function. They can be connected to other computers or recording systems for further evaluation. These intelligent components are independent from Level 1 or Level 2 automation system. For supervision purposes they are individually connectable. The efficiency of such “intelligent” systems is monitoring and incident-based maintenance without “data mining” tools; extended operation time by avoiding periodic maintenance providing reliability and process stability. Figure 16 gives an example for a local embedded system, the intelligent Sieflex®-HT spindle.

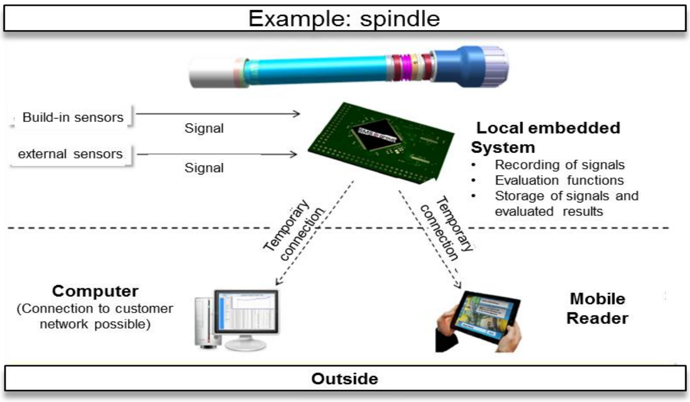

Figure 16: Different cooling technologies

5. CONCLUSIONS

The enduring challenge steel producers are facing is to ensure the competitiveness of production by improving plant performance at moderate investment. In order to support producers meeting this target, SMS group defined specific Performance Modules along the whole plant portfolio to be retrofitted in existing plants. The Modules – comprising components, redesigned features or systems - are qualified by improvements in the main categories productivity, efficiency, Industry 4.0 and quality. In the paper some selected examples to be applied in hot rolling mills are presented. They may serve as inspiration and perhaps may result in a closer look or investigation in the hidden potentials of the existing equipment.

BIBLIOGRAPHY

Krämer, S.; Holz, R.: Value-adding revamps and modernization modules – Make the best of your flat rolling mill. Proceedings, ABM week September 26 – September 30, 2016, Rio de Janeiro, Brasil.

Peretic, M.; Watson, K.; Reichel, H.; Krämer, S.: Flexible HRM solutions for highest product quality and economic efficiency in a dynamic market.Proceedings, AISTech Conference May 16, 2016 – May 19, 2016, Pittsburgh, PA, USA.

Robic.R.;Vaccani, A.; Schmidt, D.; Sprung, C.: Heavy plate mill of Acroni – Rolling mill and heat treatment line modernization for a producer of special steel grades. Proceedings, ESTAD Conference June 15, 2015 – June 19, 2015, Düsseldorf, Germany