NEW HOT ROLLING TECHNOLOGIES FOR ADVANCED STEEL GRADES[1]

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Abstract

Up to now, availability of the mill equipment and accuracy of the achieved geometrical tolerances where most important criteria for a successful and profitable production of Hot Rolled Strip and Plate. The fulfilment of these criteria is also a precondition for the development of new steel sheet products, which ensures the competitiveness of a mill operator in the future markets. Worldwide, we can expect a fast growing importance of automotive and line pipe applications. Especially in these fields a number of new steel grades have recently been developed or are actually under development. Such steel grades are > Dual Phase Steel; > Complex Phase Steel, >TRIP Steel (TRansformation Induced Plasticity), >IF Steel (Interstitial Free), >API X-Grade Steel. Besides the continuously stringent requirements on the geometrical tolerances and mechanical properties hot rolling of such steel grades is relatively complex and difficult, especially when using the conventional hot rolling process with several reduction passes in a mostly reversing roughing mill and then achieving the final gauges in the 6 or 7 stand finishing mill. It usually ends up with a significantly reduced yield, unless special measures are undertaken to control the special behaviour of these materials

Key-words: Hot rolled strip; Plate.

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2 SMS Demag

INTRODUCTION

Specific technologies and features have recently been developed and can thus contribute a lot to the so important stability of the rolling process when producing such advanced steel grades. A few of them will be presented here, which illustrate, how such solutions support our customers in safeguarding their successful future by developing new products.

Roughing mill

- Temperature wedge
- Transfer bar camber
- Transfer bar wedge
- Cold head and tail ends

- Proper furnace temperature control
- Uniform furnace temperature,
  Strong side guides and
  roll alignment control
- Proper levelling in RM
- Sequencing, crop optimization

Figure 1. Challenges and measures for proper transf

When we look into the roughing mill, we find wedge and camber due to several reasons as a major source of trouble in the further rolling process. Therefore it is important to take great care of the furnace temperature control in the first place. Another big help is the use of a so called Roll Alignment Control in conjunction with Hydraulic Roll Gap Adjustments and strong side guides on entry and exit side of the Reversing Roughing Stand.
The roughing mill should deliver a straight intermediate slab to the finishing mill, free of wedge and camber. This has been impossible, if the incoming slab already had a wedge.

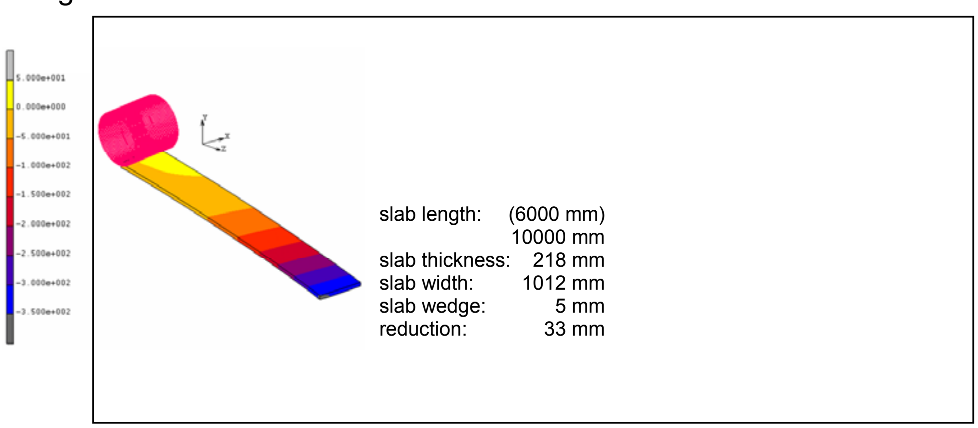
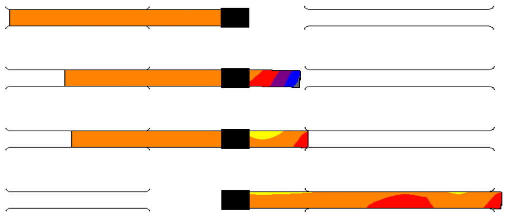


Figure 2. FEM Analysis of rolling a 218mm slab with 5mm wedge

This FEM Analysis (Figure 2) of a slab 6000mm long, 1012mm wide with an initial wedge of 5mm shows a camber after a 33mm draft of more than 350mm.

This can now be avoided by making use of strong hydraulically operated side guides on the entry as well as on the exit side of the reversing roughing stand and our Roll Alignment Control RAC (Figure 3).



slab length:	(6000 mm)
	10000 mm
slab thickness:	218 mm
slab width:	1012 mm
slab wedge:	5 mm
reduction:	33 mm

Figure 3. Elimination of wedge and camber

The applied side guide forces generate an increased longitudinal tension in the same side of the slab. At the same time the RAC performs a controlled levelling of the roll gap with resulting increased roll separating force on the opposite side. Both together generate a transversal material flow and both the wedge and the camber are nearly eliminated.

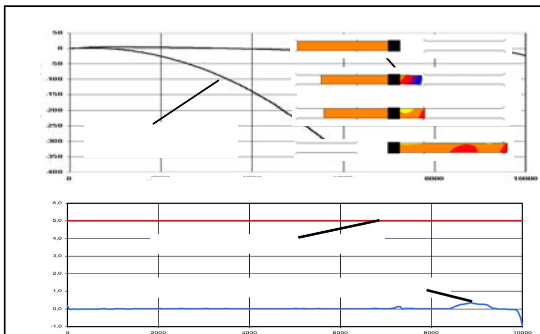


Figure 4. Elimination of wedge and camber

The FEM result (Figure 4) shows, that the remaining camber of a 10m long slab is less than 20mm and the residual max. wedge is less than 0.4mm.
In practice the side guide forces are reduced to minimize the wear and prevent damage of the slab edges. So the elimination of camber and wedge is distributed over the 5 or 7 roughing passes. The final result is the same as can be seen on these pictures (Figure 5).

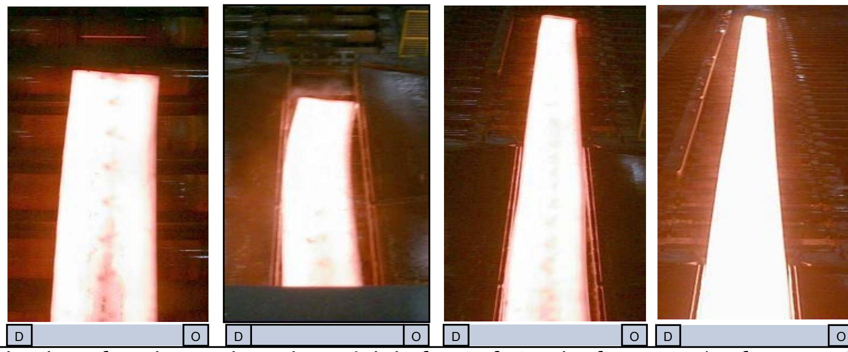


Figure 5. Elimination of wedge and camber: slab in front of stand, after pass 1, after pass 3, after final roughing pass

In the Finishing Mill a large number of sub processes are dependant upon each other and lead to extreme complexity, especially with such high demanding materials like the recently introduced high strength steels and thin gauges.

- Highest precision of roll gap geometry
- Material softening/hardening
- Critical low target profiles and extreme sensitivity to profile deviations
- Sensitivity to strip tension
- Critical strip steering
- High danger of ripped tail ends

- Automatic calibration procedure
- Setup and inbar control with recrystallization model
- Powerful profile, contour and flatness control
- Hydraulic looper with fast tension and mass flow control
- Differential tension measurement and automatic levelling control
- Tail-out monitor

Figure 6. Challenges and measures in the finishing mill

Only a few of the most important items are listed here (Figure 6), which help to secure a stable rolling process.

Highest precision is mandatory. This is supported by automated calibration procedures.

The proper setting of the mill is a precondition for achieving the steadily increasing demands on geometrical tolerances and mechanical properties. The correct prediction of the roll force also guarantees the availability of the full control range of the in bar controls. This is important to be able to master e.g. variations of material hardness.

There is always a high risk of cobbles, if the flatness in the finishing mill is not sufficient. For this reason, the control of Profile, Contour and Flatness of the rolled strip needs to be very powerful, in respect to both the completeness of the model as well as the actuators like CVC$^{PLUS®}$ shifting and bending systems.

Fast hydraulically driven loopers with low inertia and low friction together with an appropriate tension and mass flow control are essential as well.

The application of differential tension measurement in conjunction with automatic levelling control is significantly stabilizing the strip flow with ultra thin gauges.

In addition this information is effectively used in the tail-out monitor to prevent ripped tail ends.

All these technologies have been developed recently and successfully implemented. In the following, a few of them shall be explained a little bit more detailed.

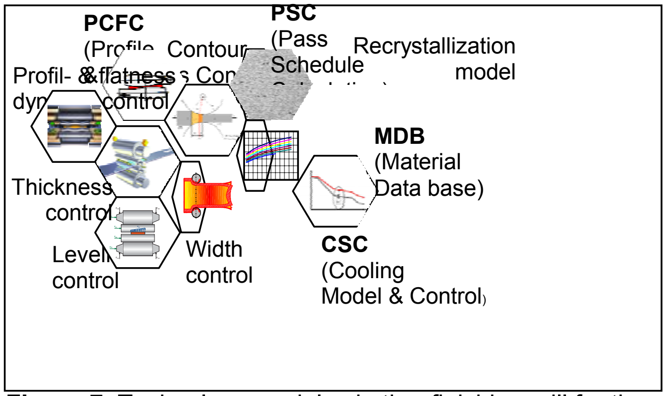
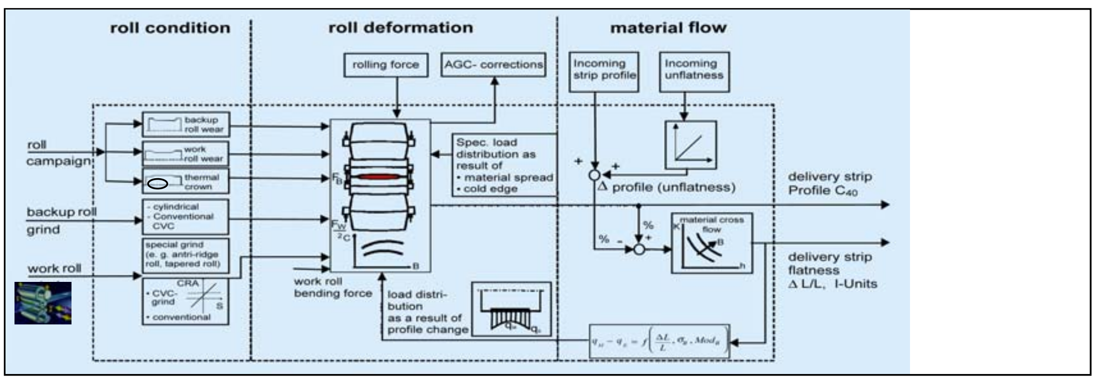


Figure 7. Technology modules in the finishing mill for the production of high-strength steel hot strip

The complexity of the sub processes in the finishing mill requires also a combined set of technological, mechanical and control solutions (Figure 7). One extremely important module is the Profile, Contour and Flatness Calculation.



PCFC with CVC PLUS ®
provides necessary performance
for demanding steel qualities

Figure 8. Essential functions of profile, contour and flatness model

The Rolling Process of high strength steel requires extraordinary degree of accuracy in determining the process values. This accuracy is provided by the implemented physical models for roll condition, roll deformation and material model (Figure 8). It is important to know, that - in opposite to soft and medium-hard material grades – when rolling high-strength material grades there is no longitudinal material flow in the interstand area, which would allow to accept certain roll gap errors or unflatness. In fact, relative parabolic errors in roll gap of about 3-5 µm lead in the delivery-end stands to overrolling due to the summation of the flatness error and thus direct to a failure of the rolling process.

So this PCFC-model is able to measure the relatively high dynamic changes of the process variables and compensates them via the work roll bending system. Together with the effective CVC$^{PLUS®}$ shifting system in the first stands of the finishing train, the newly developed models achieve stable profiles of 40 µm or less at a strip thickness of below 2.1 mm.

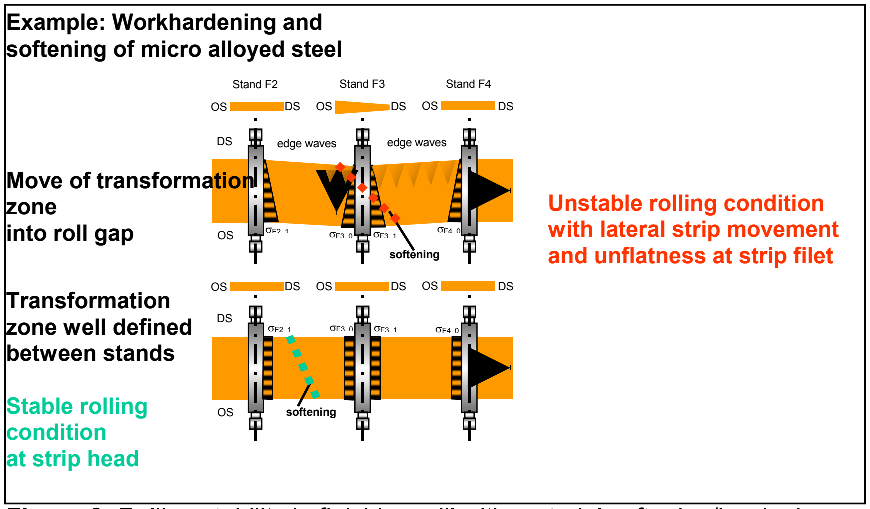


Figure 9. Rolling stability in finishing mill with material softening/hardening

Hot Rolling of micro alloyed materials on a conventional Hot Strip Mill is difficult also because of the relatively large temperature differences between head and tail end. This material is characterised by different recrystallization behaviours in longitudinal and transverse direction dependant on the temperature. If an area of recrystallization or softening moves from the interstand area into the roll gap (Figure 9), an immediate instability of the rolling process will occur, which usually ends in a cobble. Rolling would remain stable if the softening zone could be fixed between the stands.

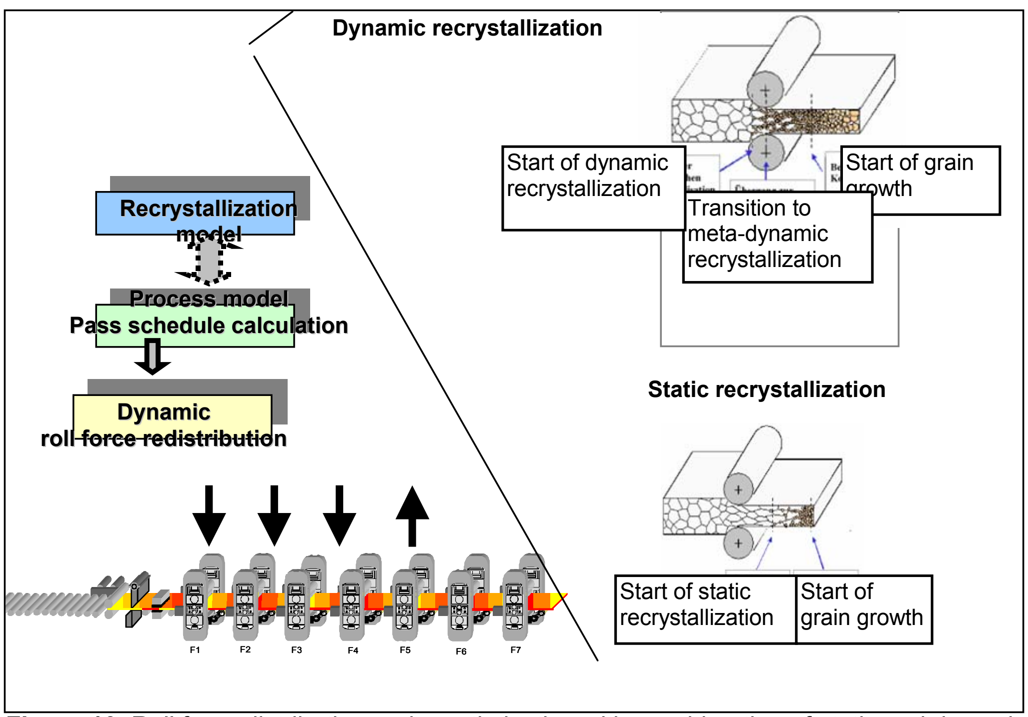


Figure 10. Roll force distribution and – optimization with consideration of static and dynamic recrystallization

After having developed a reliable recrystallization model (Figure 10), we are now in the position to describe exactly, where static and dynamic recrystallization will take place. Using this information as an additional input into the pass schedule calculation, we can always select a draft distribution, which makes sure over the whole strip length that the strip will always be softened by dynamic recrystallization before entering the roll gap. This ensures a stable rolling condition.
All these features, together with all the others which have not been described here in detail, we can achieve excellent profile, thickness and flatness performance in a stable and reliable rolling process.
The production of multiphase steels (DP and CP) is making use of a powerful cooling model and the respective control of the strip cooling section (Figure 11).

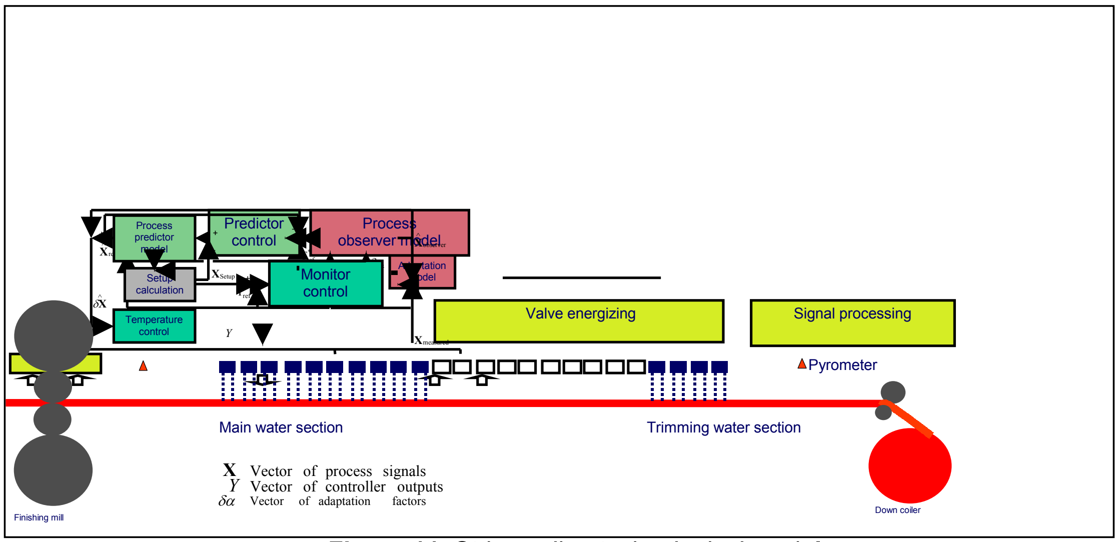


Figure 11. Strip cooling technological model

Depending on the target properties of the rolled product, a suitable cooling strategy needs to be selected. Very high and flexible cooling rates can be applied by making use of an additional compact cooling box.

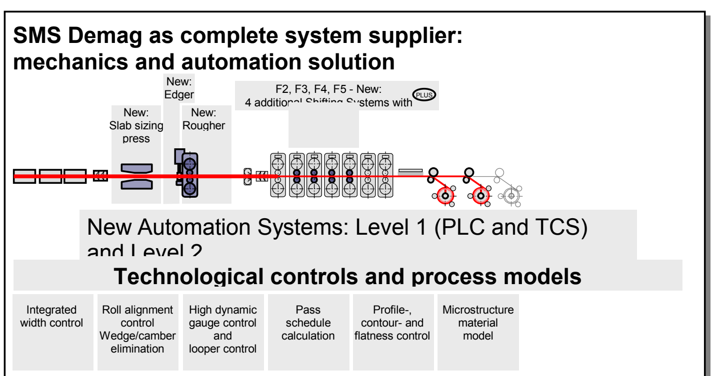


Figure 12. Salzgitter Flachstahl GmbH, Germany – Modernization of a HSM

An example for the implementation of all these features is the large modernization project of Salzgitter Flachstahl in Germany. This 80" wide hot strip mill was installed in 1963.

The recent modernization project was executed in two steps. In a first modernization step a new slab sizing press had been implemented. By this, the number of slab

formats were reduced and the efficiency of the steel melt shop and slab caster were improved.
The second step replaced the existing roughing stand with a completely new one with attached vertical edger stand.
Furthermore the finishing stands F2-F4 received CVC Plus® systems. Overall the complete automation systems have been replaced by SMS Demag. All of the mentioned models and technological controls were developed and successfully implemented.

Figure 13. Salzgitter HSM revamp – Installation of preassembled roughing stand.

In order to minimize the shut down of the plant the complete roughing stand was assembled parallel to the rolling mill and moved to its place by hydraulic lifting devices after dismantling the old roughing stand (Figure13). The total weight of this moved assembly was about 850 tonnes.

Figure 14. Salzgitter HSM revamp – restart after less than 18 days

After a shutdown of less than 18 days the mill could start up again with regular rolling from the first slab on.

NOVAS TECNOLOGIAS DE LAMINAÇÃO A QUENTE PARA QUALIDADES AVANÇADAS DE AÇOS[1]

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Resumo

Até o presente a disponibilidade dos equipamentos de laminação e a exatidão das tolerâncias geométricas obtidas eram os critérios mais importantes para a produção bem sucedida e lucrativa de tiras e chapas laminadas a quente. O cumprimento destes critérios é, também, prerrogativa para o desenvolvimento de novos produtos de chapas que asseguram a competitividade do empresário operador de uma usina de laminação no mercado futuro. No âmbito mundial a expectativa é grande de um crescimento rápido da importância de aplicações automotivas e em tubos. Especialmente nestes campos foram desenvolvidos recentemente diversas novas qualidades de aço ou encontram-se em fase de desenvolvimento. Trata-se de > aços de duas fases; > aços de fases complexas; < aços TRIP (plasticidade induzida por transformação); > aços IF (livre de interstício); > aços grau API X. Além do estreitamento cada vez maior das exigências em relação às tolerâncias geométricas e propriedades mecânicas, a laminação a quente de tais aços é relativamente complexa e difícil, especialmente quando se usa o processo convencional com a redução em diversos passos na maioria das vezes em laminadores reversíveis para então obter a bitola final na 6ª ou 7ª gaiola. Isto, geralmente, tem como conseqüência um rendimento reduzido, a não ser medidas especiais sejam tomadas para controlar o comportamento especial destes materiais.

Palavras-chave: **Tiras e chapas laminadas a quente**.

[1] *Contribuição Técnica ao 42º Seminário de Laminação Processos e Produtos Laminados e Revestidos; 25 a28 de Outubro de 2005, Santos, SP, Brasil.*
[2] *SMS DEMAG AG*