

## CUTTING EDGE TECHNOLOGY FOR HSM – STRIP STEERING CONTROL \*

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### **Abstract**

Stability of the hot strip mill rolling process remains a main topic when it comes to processing thin and hard materials. Strip steering especially at the end of rolling and tail out rips are a main source of unscheduled down times in a hot strip mill. Main focus of this paper is the new X-Roll<sup>®</sup> Guide system to improve mill stability and quality. An overview of SMS group developments in the recent years regarding equipment and control strategies is given. The new side guiding system in the entry area of the finishing mill is introduced and explained with operational examples. The system provides reproducible conditions for the threading process and during rolling. Steering control has a direct benefit on the availability of the mill. New developments of the roll alignment control strategies based on roll force and mill stand entry guide force measurement will be presented. Additionally a camera based measuring system is introduced that generates a direct process feedback of the strip position. It provides together with the roll alignment control the necessary control parameters for adjusting the roll gap and guiding the strip correct centered through the mill. As a summary the SMS group system is explained combining all features.

**Keywords:** Hot strip mill; yield; rolling assistance; X-Roll<sup>®</sup> Guide.

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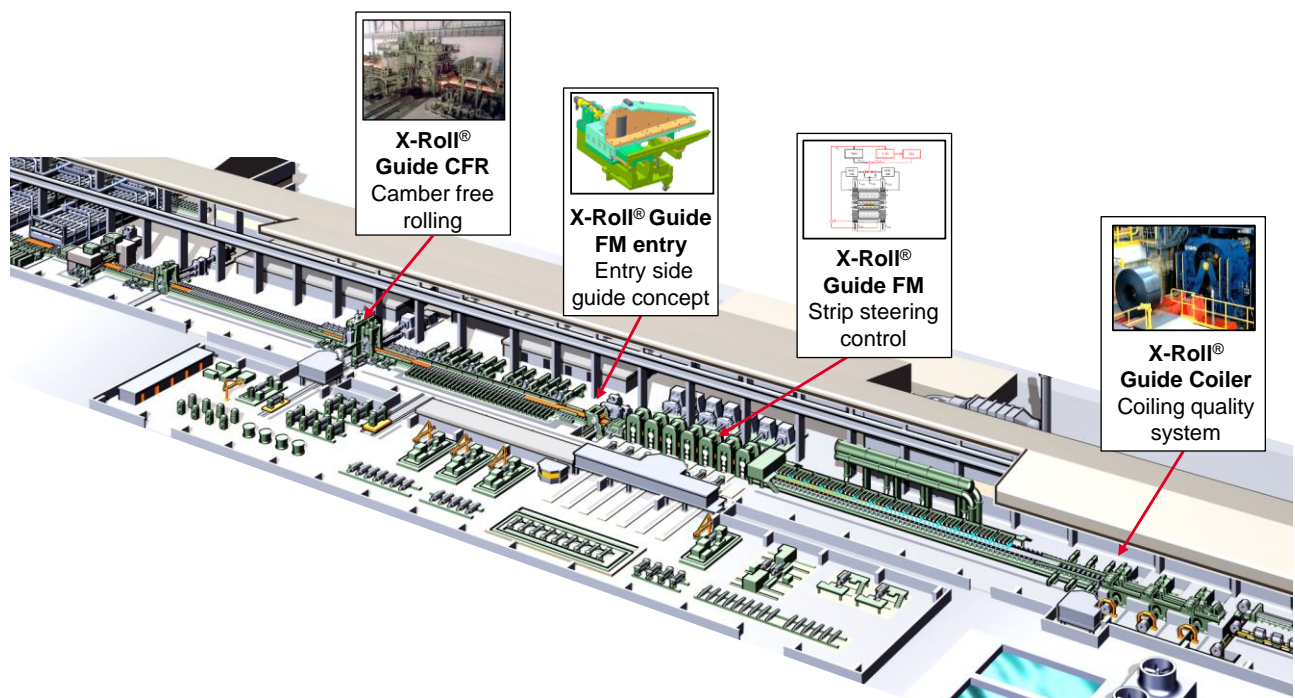
## 1 INTRODUCTION

In hot rolling the stability of the process is a major issue for commercial success. The strip steering is the key factor to avoid cobbles, wrapped strips and surface defects due to marked rolls. The different process steps – roughing, finishing and coiling – require different measures to assure a straight, wedge free and centered strip.

Figure 1 shows a typical hot strip mill layout [1]. After discharging from the furnace the roughing mill reduces the slab from 220 mm to 280 mm thickness to the transfer bar thickness of 22 mm to 60 mm. Main quality parameters of transfer bars are thickness and profile uniformity and a straight and camber free shape.

situation at thicker gauges. At thinner gauges the strip will be damaged with the side guide contact. The double rolled thickness can cause strip breaks, marked work rolls, affect the strip edge quality etc..

In the finishing mill the roll levelling at the consecutive mill stands is essential to rolling stability. Threading in is one task to fulfill. The operator has to observe the strip head movement and must react very fast to correct the levelling. During rolling the filet – when the strip is under tension – the process is very stable and only little operator intervention is necessary. The tailing out is a very short but most instable process phase. The operator has only little chance to do any corrections. Especially at the last stands the rolling speed is too fast to interfere and do the correct leveling.



**Figure 1:** Typical Hot Strip Mill layout with strip steering systems [1]

Camber and wedge in transfer bars can only be rolled up to a certain value in the finishing mill. The tail end becomes more and more off centered when it is passing through the finishing mill stands. The side guiding systems in finishing mill inter stand areas can only correct the off center

In the down coiler area the final product of the HSM is generated. One coil quality parameter is rectangular shape. Side guides in front of the coiler assure a centered winding of the first wraps. A proper coil build up is difficult to achieve if

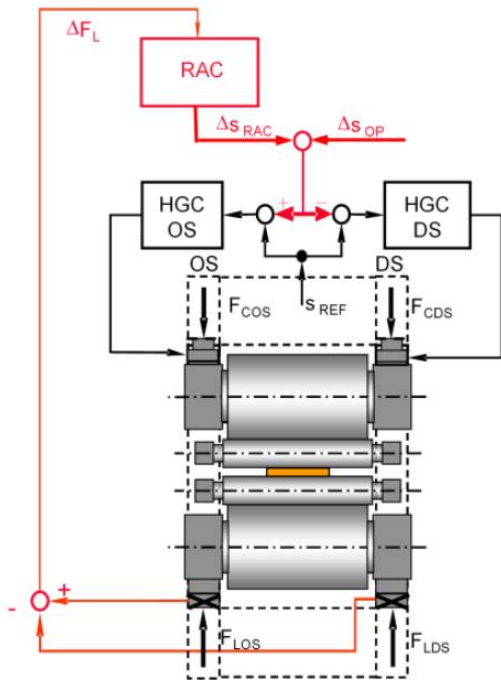
the strip is cambered and telescopicity is unavoidable.

SMS-group developed in the recent years equipment and automation solutions for all mill areas to improve the stability of hot rolling. This paper gives an overview on the state-of-art X-Roll® Guide system for hot rolling mills.

## 2. ROUGHING MILL WEDGE AND CAMBER CONTROL

The roughing mill has the task to transform the incoming slab into a transfer bar with typical quality parameters of

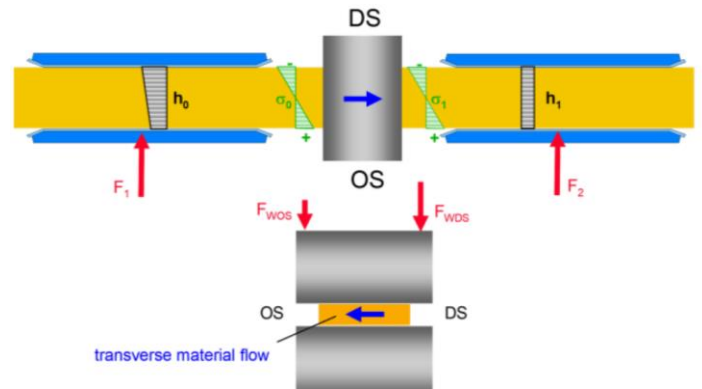
- uniform thickness <math><1,5\%</math>
- wedge in cross profile <math><0,5\%</math>
- camber (straightness) <math><30\text{mm}</math>



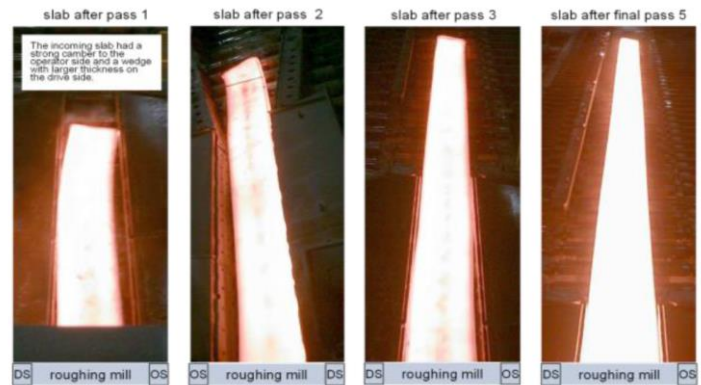
**Figure 2:** Roll Alignment Control (RAC) for a roughing mill stand [1]

Thickness accuracy and wedge control must be done in most roughing mills without any thickness measurement device. Only the roll force and the cylinder position can be used to control thickness and wedge. Figure 2 provides a sketch of the technological control system for roll tilting of SMS group at the roughing mill stand.

Based on the force measurement at the load cells the differential force between operator and drive side is forwarded to the automatic gauge control system. A roll gap control model to describe the impact on elastic behavior of the mill stand has been developed since the early 70s. The Roll Alignment Control (RAC) systems based on this model are proven technology since the 90s. With these control systems thickness and wedge can be controlled precisely.



**Figure 3:** Working principle of X-Roll® Guide CFR [1]



**Figure 4:** Strong slab camber rolled with X-Roll® Guide CFR [1]



Other upstream processes have a large impact on the camber performance of a roughing mill:

- wedge and/or camber from casting,
- nonuniform heating of the slabs over width,
- wedge and/or camber from proceeding roughing passes and
- off center of bar during rolling.

SMS group developed the X-Roll® Guide CFR system [2] to improve the camber and wedge performance, see figure 3. Strong side guides are in operation during rolling and not only for centering in between roughing passes. These side guides are active on the entry and exit side of the mill stand. Both guiding and roll aligning are required to adjust wedge and camber independently.

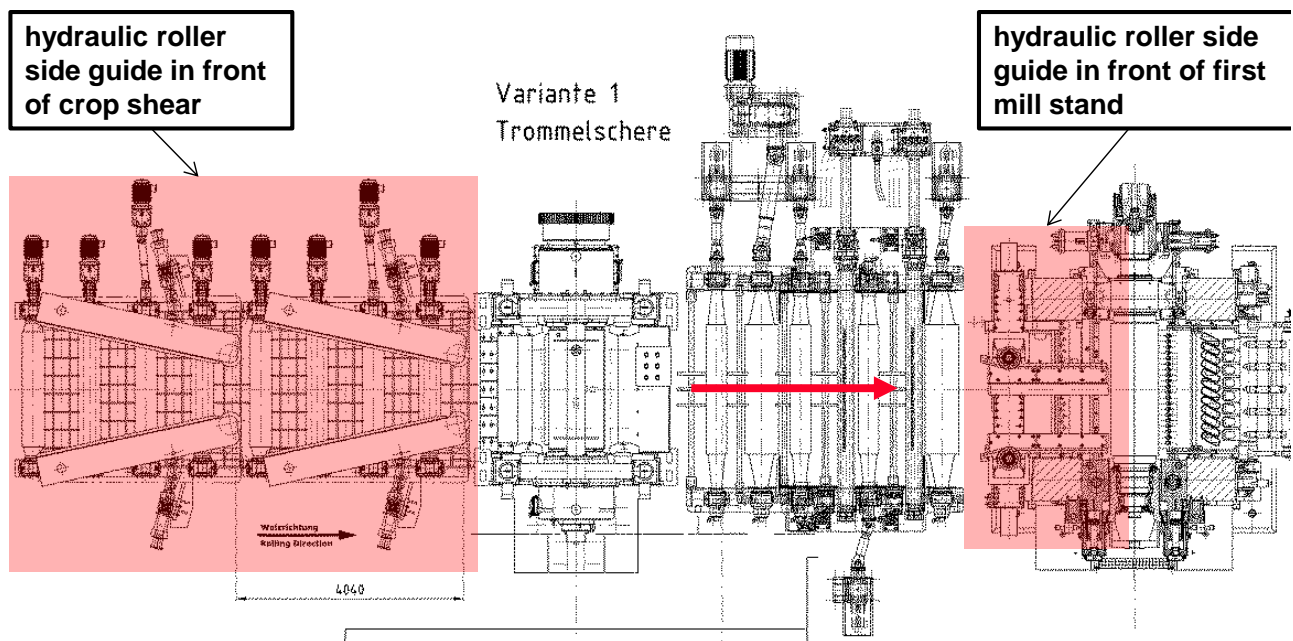
X-Roll® Guide CFR system results can be observed in figure 4 which shows the rolling of a transfer bar with a strong wedge and camber. From pass to pass the transfer bar is straightened and the wedge is eliminated.

### 3. FINISHING MILL ENTRY

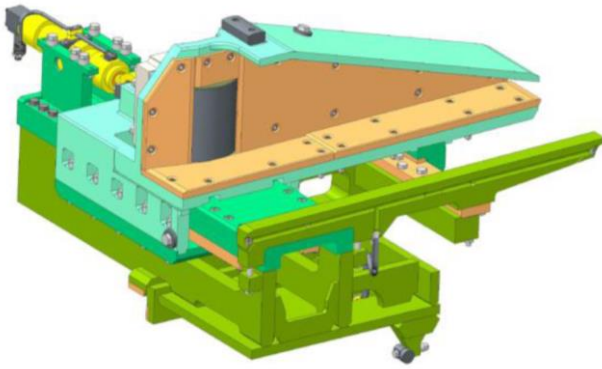
When the transfer bar is transferred to the finishing mill it has to be centered. This is done to achieve a straight and centered threading of the finishing mill. After start of rolling in first finishing mill stand the strip position can only be corrected slowly and with high force.

The X-Roll® Guide FM entry system of SMS group is shown in figure 5. It is designed to provide a long guiding length. A good alignment of the transfer bar requires centering at more than one point along the bar length. Therefore the strip is centered in front of stand F1 and in front of the crop shear. This reduces the required forces to center the strip progressively.

All guides are equipped with large rolls to avoid strip edge damages. To increase the life time the rolls have a wear resistance surface (figure 6). Flexible positioning during threading allows adaption to any transfer bar shape. The system is active during the whole rolling process to align the strip over the total length [3].



**Figure 5:** Mechanical design of X-Roll® Guide FM entry [1]



**Figure 6:** Stand F1 entry guiding table, drive side [1]

#### 4. FINISHING MILL INTER STAND AREA

The strip threading and especially the tailing out process are the most critical rolling phases in the FM. They cause most of the disturbances and can lead to ripped and folded head and tail ends, to work roll damages and in the worst cases to cobbles and mill down times.

The SMS group combined all the strip steering components in the X-Roll® Guide FM system.

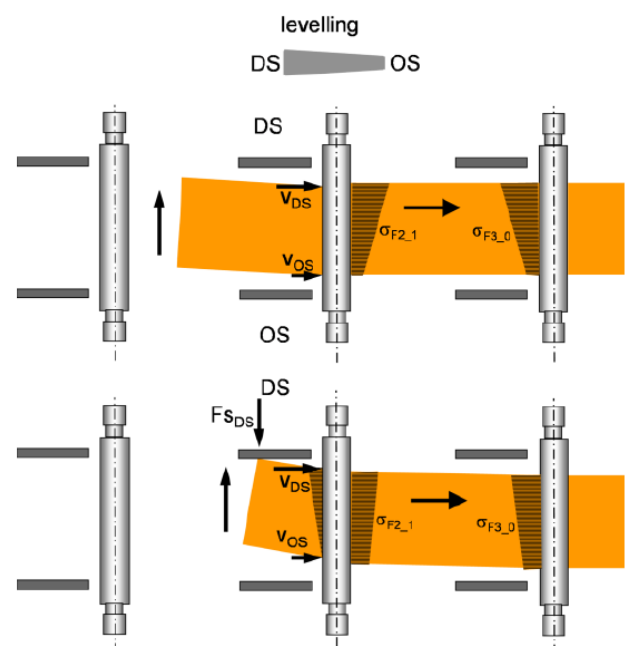
All mill stands are equipped with the RAC system similar to the one at the roughing mill stand. For mill stands with hydraulic work roll shifting systems the Thrust Force Compensation (TFC) [4] can be added to compensate axial forces, which can disturb the measurement if the differential forces.

The X-Roll® Guide FM system is completed with the Tail Out Monitor (TOM) which calculates the levelling error for each mill stand and displays a levelling amount and direction after each strip. The operator can use this levelling recommendation to prelevel for the next strip.

In FM with separately driven hydraulic side guides it is possible to detect when and where a strip tail end hits a side guide (figure 7). This information can also be integrated in the RAC to improve the

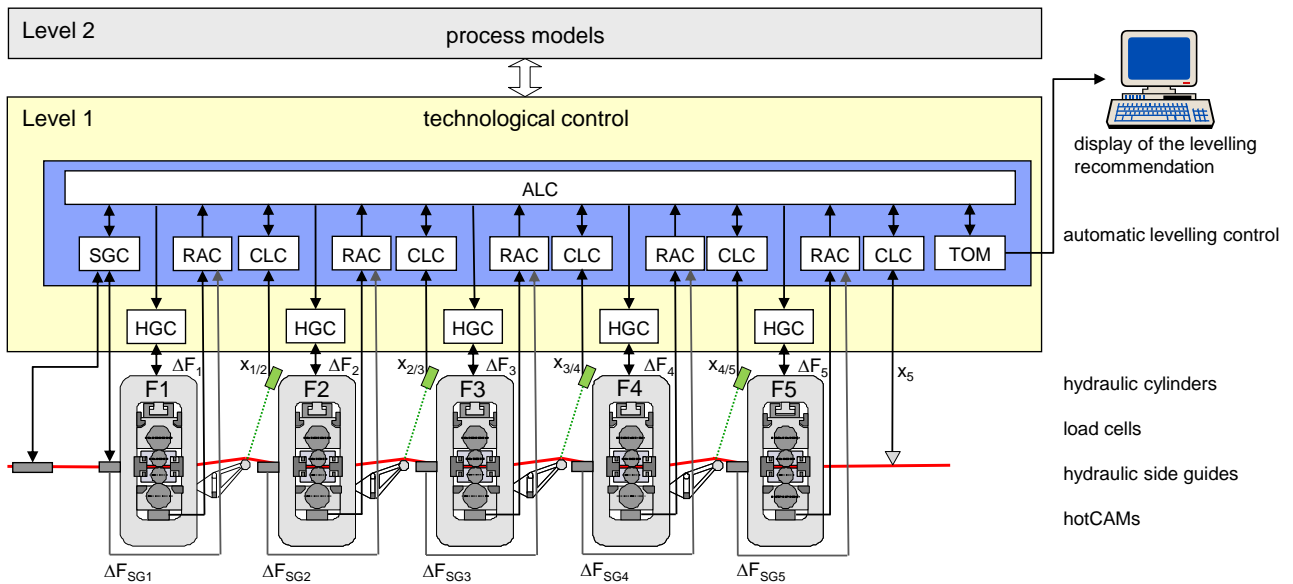
performance and to stabilize the tail out process.

A new optical sensor which supplies the inter stand strip position for a direct center line control is under development. With this camera system working in the infrared frequency spectrum together with a fast digital image processing system the position of the strip can be measured. The so called hotCAM System is positioned on the top of the mill stand and thus protected very well [5].



**Figure 7:** Threading out at finishing mill [1]

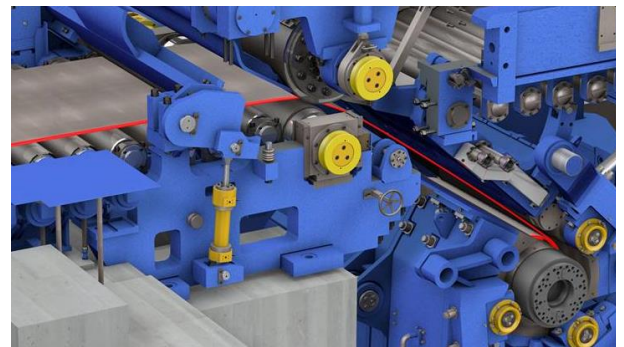
The generated strip center signal is transferred to the controller and used to level the mill stands. The integration of the hotCAMs in the X-Roll® Guide FM system is shown in the block diagram in figure 8.



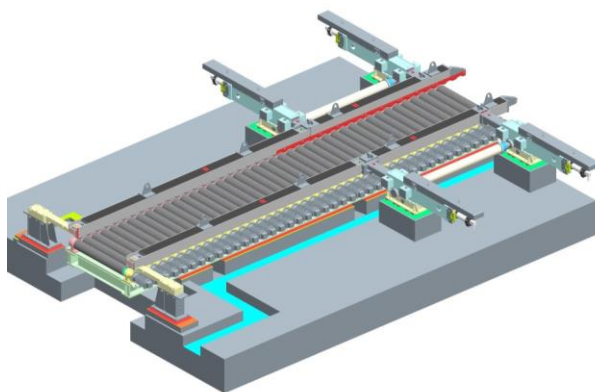
**Figure 8:** hotCAM and X-Roll® Guide FM System in inter stand area [1]

### 5. DOWN COILER AREA

To achieve a proper coil shape X-Roll® Guide Coiler was established. OS and DS side guides are operating independent hydraulic controlled, highly dynamic and with low friction. Damages at the strip edges are avoided and different control modes are selectable. In Figure 9 the general design is shown.



**Figure 10:** Active chute roll during rolling [1]



**Figure 9:** Design of down coiler side guides [1]

in figure 10. The chute roll is in contact with the strip during coiling and supports the bending process. This stabilizes the coiling process and leads to straight and tight coils with minimum telescopicity.

The coiling quality for high strength material or thick pipe grades can be improved with a controlled chute roll shown

## 6. CONCLUSIONS

Different systems to control the strip steering developed by SMS-group are explained in this paper.

- Roughing mill: X-Roll<sup>®</sup> Guide CFR; perfect transfer bar shape and reduction of wedge;
- Finishing mill entry: X-Roll<sup>®</sup> Guide FM entry; stabilizing the threading and filet rolling process
- Finishing mill area: X-Roll<sup>®</sup> Guide FM; stable threading and tail out, reduction of ripped strips and work roll damages
- Down coiler area: X-Roll<sup>®</sup> Guide Coiler; straight coils with minimum telescopicity

These systems can be added to an existing rolling plant in total or in packages. Each package has its own advantages and helps to increase rolling stability and yield of the hot strip mill. The selection of the technology packages depend on preconditions like product mix, mill condition or used automation standard.

The investment in these systems must be returned in an adequate time. In a hot strip mill the investment can be justified simply by the amount of ripped strips, downgraded material and the resulting efforts for roll change, unscheduled down times and grinding. Additional rolling time can be used to boost the production capacity. The higher the production amount of thin gauge hot strips and hard material the higher the benefits of the systems.

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