LATEST DEVELOPMENT OF PLATE AND STECKEL MILL TECHNOLOGIES[1]

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Abstract

As the economic conditions continue to remain unpredictable, the plate market is facing challenges that it has never seen before. For any new investment, the challenge is to design the plant such that it remains flexible to produce a wide range of products to cater for future demands. Siemens VAI's latest references include a unique combination of Plate and Steckel Mills into a single line and a new Plate-Steckel Mill plant. These projects ensure both production flexibility of discrete plate and coil. One key component is the use of fully automatic thermo-mechanical rolling using the latest physical models and intelligent sequencing strategies achieves the optimum in grain refinement and thus improves mechanical properties. At the same time productivity is kept as high as possible through sophisticated mill pacing. The novel profile and flatness strategy relies on comprehensive physical models and makes use of SmartCrown® as a powerful actuator, enabling large reductions to be taken without risking edge waves. Throughout the rolling and cooling stages of processing, accurate calculation of the thermal-mechanical state of the plate is performed by the temperature and micro-structural monitors. This enables tighter control of the final plate mechanical properties by providing an insight into the plate evolution during the thermo-mechanical processing. This paper looks at the new technical features incorporated into these new mill lines.

Keywords: Steckel Mill; Plate Mill; Rolling Process Models, Microstructure Monitor.

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1 INTRODUCTION

This paper will firstly describe two major projects which are currently in the commissioning phase during 2013. These two projects are a Plate and Steckel Combination Mill Line in South America and a Plate-Steckel Mill in Central America. The following sections will then go on to describe key technologies included in these projects. These improved technologies will result in better equipment performance and tighter tolerances to product geometrical and mechanical property specifications.

2 PLATE AND STECKEL COMBINATION MILL LINE

In 2010, Siemens VAI Metals Technologies received an order for a new combined Plate and Steckel Mill plant in South America. The project includes the engineering, equipment, supervision of installation and commissioning. The flat products (plates and coils) will be mainly supplied to the domestic market.
The Plate Mill line consists of 1 Reheat Furnace, 4-high Plate Finishing Mill Stand, complete with SmartCrown® technology, Pre-leveller, MULPIC® plate cooling machine including DQ, Hot Leveller, 1 Disc-Type and 1 Heavy Plate Walking Beam Type Cooling Bed, Shearline with Double Side Trim Shear and Divide Shear, Test Piece Shear, Pilers and Cold Leveller in order to achieve a production of 1,100,000 tonnes per year of plates. The Steckel Mill line consists of 1 Reheat Furnace, Rotary Crop Shear, 4-high Steckel Mill Finishing Stand complete with SIROLL SmartCrown® technology, Coiler Furnaces, Laminar Cooling, Downcoiler and Coil Handling in order to achieve a production of over 800,000 tonnes per year of hot rolled coils.
Both the Plate Mill line and the Steckel Mill line have provision for expansion to increase production in the future. The Plate Mill line includes provision for the addition of a Roughing Mill Stand, a Vertical Edger, a second Cooling Bed, a Crop Shear in the first shear line and a second shear line. The Steckel Mill line includes provision for the addition of another Reheat Furnace, a Roughing Mill Stand and Edger, three Tandem Mill Stands after the Steckel Mill Stand and a second Downcoiler.
Siemens VAI is engineering and supplying the complete electrics and automation systems for both lines, including main and auxiliary drives. Siemens VAI SIROLL MSM (Microstructure Monitor) is also included in the Plate Mill for online quality assurance. A comprehensive training package is provided by Siemens VAI Metals Technologies to plant operators, production managers and maintenance personnel to ensure a quick and successful start up of the new plant.
Figure 1 shows the line layout for the combined Plate and Steckel Mill solution

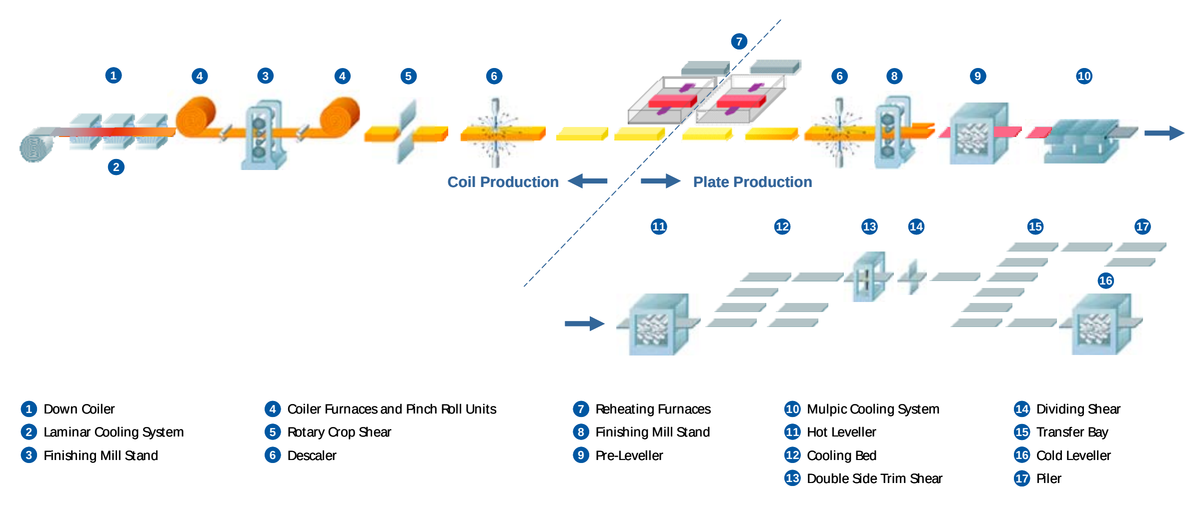

Figure 1. Typical plate and steckel combination mill layout.

Typical Design data

Plate Mill

Plate thickness 4.5–150 mm
Plate width 900–3,600 mm
Finished plate length 18 m max
Nominal rolling force 85,000 kN
Motor power 2x 8,500 kW

Steckel Mill

Strip thickness 2.0–20.0 mm
Strip Width 900–2,100 mm
Nominal rolling force 55,000 kN
Motor power 2x7,000 kW

Annual Production (1st Phase): (plates and coils) 1.9 Mtpy

Products: Structural Steels, Pipeline Steels, HSLA, Shipbuilding Plates, Pressure Vessel

3 PLATE-STECKEL MILL LINE

In 2013 the new Plate-Steckel mill started up in Central America with the production of discrete plate and coils. The nominal annual production capacity is 1,000,000 tonnes of hot rolled products, of which 750,000 tonnes is hot rolled plate and 250,000 tonnes is hot rolled coil. Siemens VAI were specifically responsible for the engineering design and co-ordination for the Plate-Steckel Mill process technology, technical services including training, auxiliary equipment management and complete electrical and automation for the Furnace, Mill and Shearline. Figure 2 shows the line layout for the Plate-Steckel Mill solution.

The Plate-Steckel Mill line consists of 2 Reheat Furnaces, Rotary Crop Shear, 4-high Plate-Steckel Mill Finishing Stand complete with SIROLL SmartCrown® technology, Coiler Furnaces, Laminar Cooling, Downcoiler and Coil Handling. The Shearline consists of 2 Disc-Type Cooling Beds, Double Side Trim Shear and Divide Shear.

This plant also has provision for the future addition of a Roughing Mill Stand and a 3rd Reheat Furnace.

Typical Design data

Plate

Plate thickness 4.0–110 mm
Plate width 1400–3,250 mm
Finished plate length 40 m max
Nominal rolling force 72,000 kN
Motor power 2x 8,000 kW

Coil

Strip thickness 2.5–20.0 mm
Strip Width 1600–2,500 mm

Products: Structural Steels, Pipeline Steels, Shipbuilding Plates

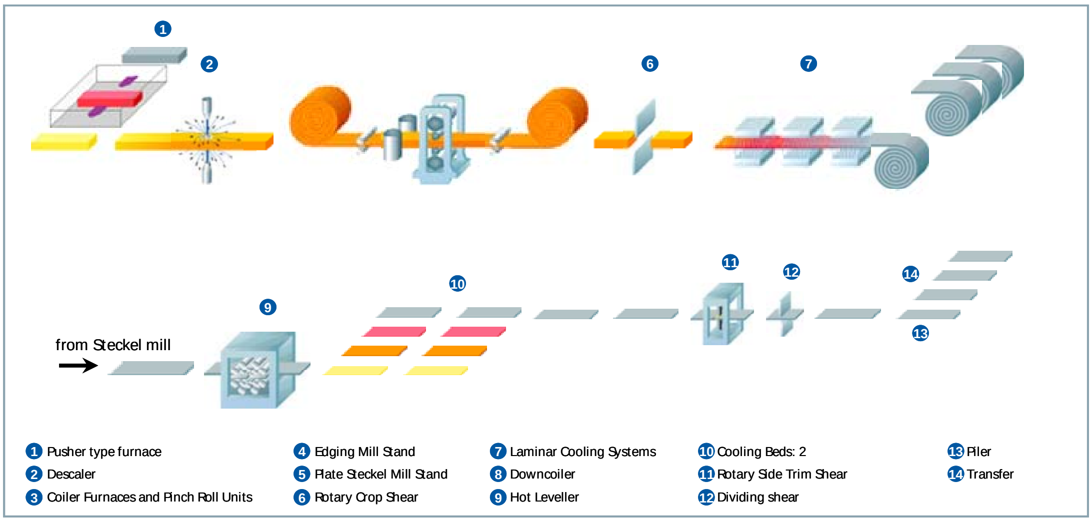

Figure 2. Typical plate-steckel mill layout.

4 MILL STANDS

The most fundamental aspect of designing a rolling mill is the operator's target market.(1) The key parameters of the intended product mix translate not only into width, thickness and piece weights for the finished product, but also into the strain-temperature path of the process, since it is this that will determine material properties. This in turn determines the rolling forces, torques and other key equipment parameters. The product mix thus dictates the whole process solution. The main selection factor for the mill type is the final thickness and width of the plate and the application. For grades greater than 25mm thick and where high strength and toughness in certified applications (such as pipelines and shipbuilding) are important then a conventional Plate Mill is generally the appropriate solution. Conversely if the product requirement is for coil in the range 2 to around 15 mm thickness, then the Steckel Mill is the best solution for widths up to ~2 metres.
Figure 3 shows the typical product mix in terms of thickness, width and strength that can be produced on different types of mills. It is clear that a line consisting of a combination of a Plate Mill and Steckel Mill offers the widest possible product mix. Whilst a Plate-Steckel Mill offers an alterative solution with less capital investment but still the capability of rolling a wide variety of products.

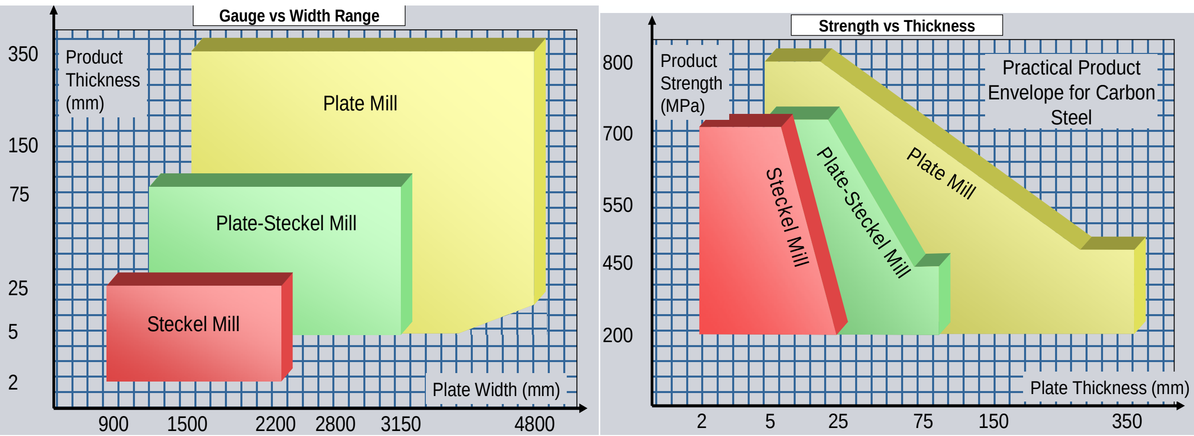

Figure 3. Typical dimension and product properties accessible by different mill types.

In Phase 1 of both projects the Finishing Mill Stands carries out both the roughing and finishing passes. In order to be able to do this the work roll diameter and drive train have been optimised for high torque in the roughing passes whilst keeping the roll diameter as small as possible in order to be able to finish roll the thin gauge products and the mill incorporates SmartCrown® technology as discussed below.

5 SMARTCROWN

One key aspect of the new plants is the incorporation of SmartCrown® technologies into the Mill Stands. Not only does this allow accurate control of the product crown and flatness but also enables higher reductions to be taken which are required to achieve the desired final mechanical properties. Figure 4 illustrates the reduction in the number of passes which can be achieved for two different products.

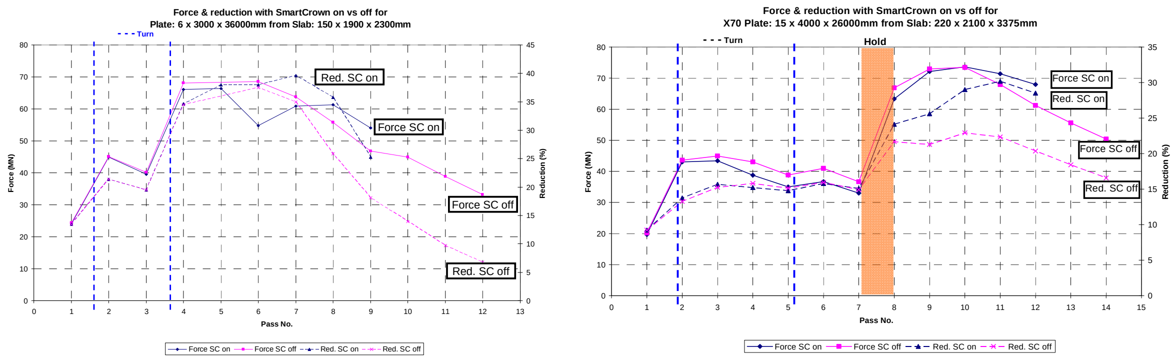

Figure 4. Reduction in number of passes with SmartCrown.

The abbreviation SMARTCrown stands for, Sine Contour, Mathematically Adjusted and Reshaped by Tilting. The SmartCrown® contour is defined by an equation and by changing parameters within the equation; the roll contour can be changed depending upon the requirement of the rolled product.(2) For example, the equivalent work roll crown range for maximum and minimum axial shift can be modified. The top and bottom work rolls are ground with the specified profile so that the two work roll barrels will produce a symmetrical roll gap under rolling load. When the work rolls are then shifted axially in opposite directions, the roll gap will change to give a negative or positive roll crown depending upon the shifting direction. Figure 5 shows the basic shifting principle.

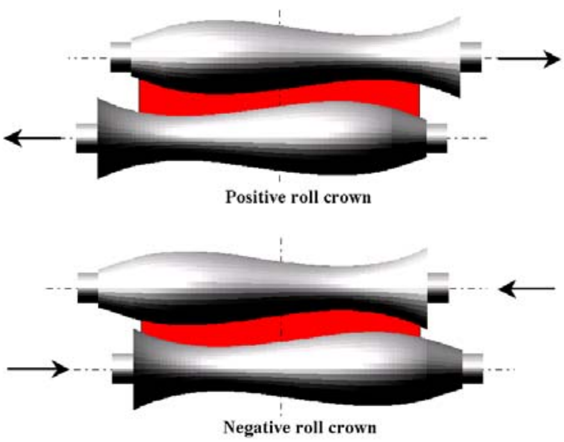

Figure 5. Shifting principle of the SmartCrown Rolls.

The work roll movement is actuated using four axial shift cylinders mounted on sliding latching frames on the roll change side of the Plate Mill Stand. These latching frames are actuated by a hydraulic latch cylinder which disconnects the work roll chocks from the axial shift cylinders at work roll change, see Figure 6. The typical range for the axial shifting is -150mm to +150mm. Each work roll is independently driven by motors through telescopic universal spindles which allows for the axial shift movement of the work rolls. During axial shifting it is important that the work roll bending force remains centred on the roll bearings. For this reason the bending force is applied by pairs of bending cylinders and the distribution of load between them is adjusted to keep the resultant force centred on the roll bearings.

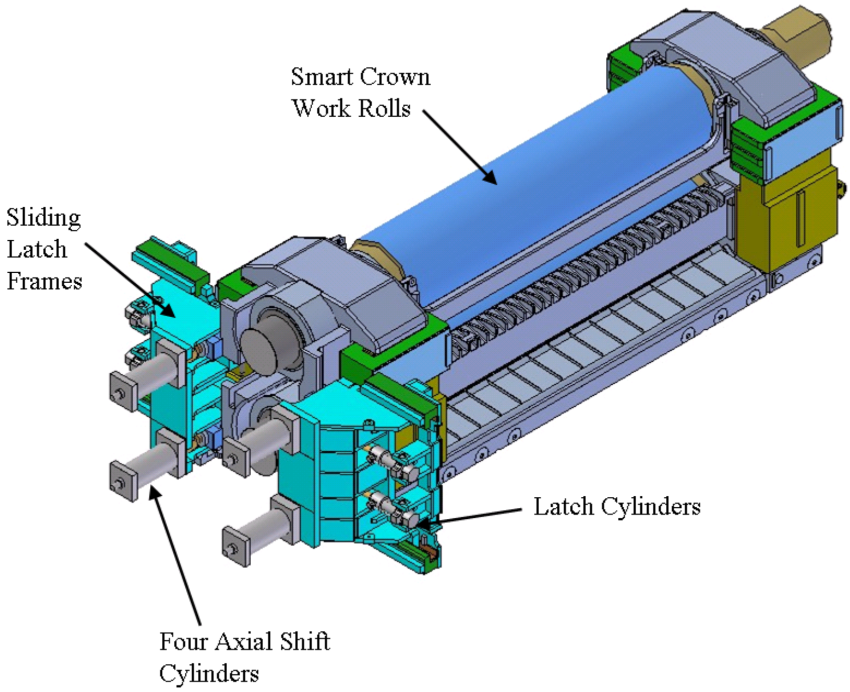

Figure 6. Work roll shift general assembly.

6 STECKEL COILER FURNACE TECHNOLOGY

The Steckel Furnaces include the latest developments from Siemens VAI. In addition to features such as the well proven 2-part flap sealing and guiding system and removable hood, the coiler furnaces include Siemens VAI patented passive deflector-roll technology for minimizing tension variations and a top guide for minimizing the risk of missing the slot when threading the drum.
It is well known that the coil build-up in a Steckel coiler is not perfectly circular and that this leads to tension variations which cause disturbances to the width and thickness. The passive deflector-roll technology was developed to absorb the changes in strip length caused by the non-circular coil diameter and thus minimize the tension variations. Figure 7 illustrates the basic mechanical layout and some dynamic simulation results which show the significant reduction in tension variations that the passive deflector can achieve.

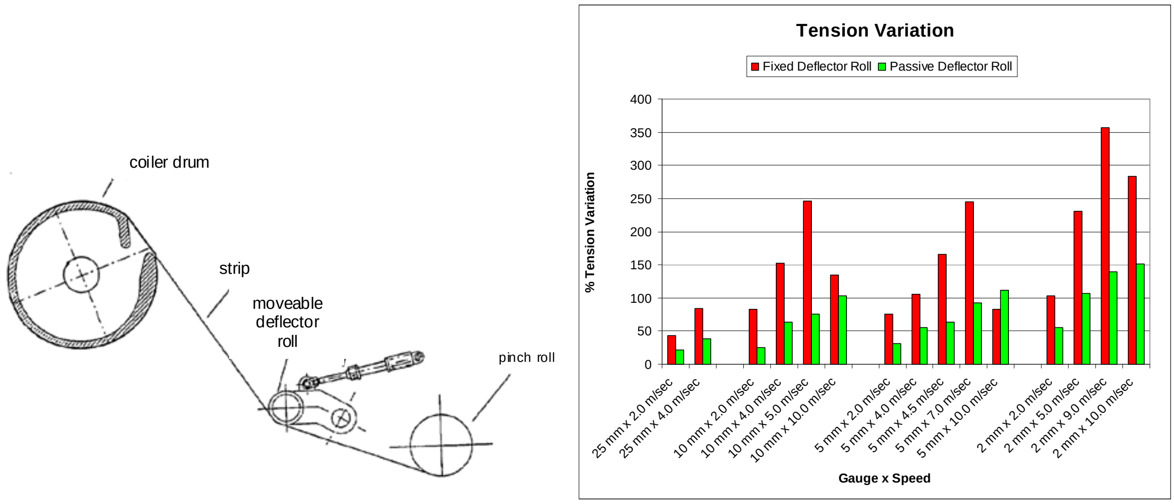

Figure 7. Passive deflector roll and simulation results.

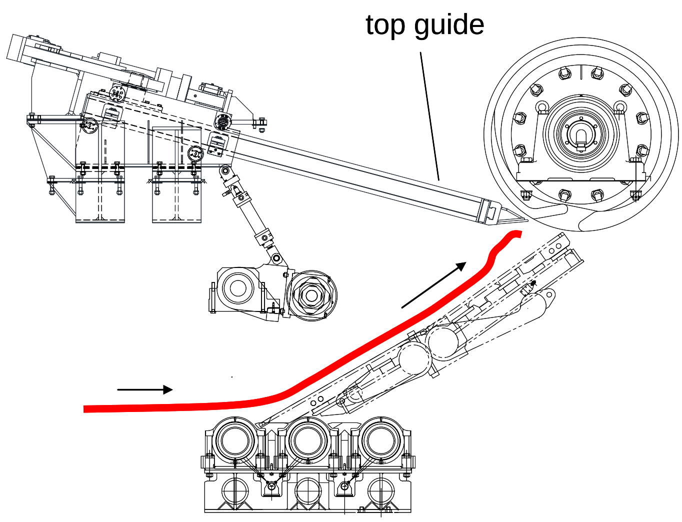

Figure 8. Steckel coiler furnace top guide.

Figure 8 shows the top guide in the Steckel furnace coiler in its operating position for strip thread. The top guide deflects the strip into the coiler drum slot to ensure that it cannot miss the slot. As soon as the strip head is in the slot the guide retracts at high speed so that the strip take up onto the coiler drum is not affected.

7 COOLING TECHNOLOGY

The MULPIC® first conceived by CRM (Centre for Research in Metallurgy) and now jointly developed with Siemens VAI, consists of 48 headers grouped into 24 opposing pairs, see Figure 9. Each header is one metre in length and will be slightly wider than the mill run-out table. Typically, headers are grouped into four banks, banks A, B, C and D, with six header pairs per bank. The top headers of each bank are mounted in a frame that is supported at each corner on a jacking system. When rolling non-cooled plates the top banks are 1200mm above the run-out table. The headers are lowered to as little as 500mm above the plates when the switch is made to cooling mode.

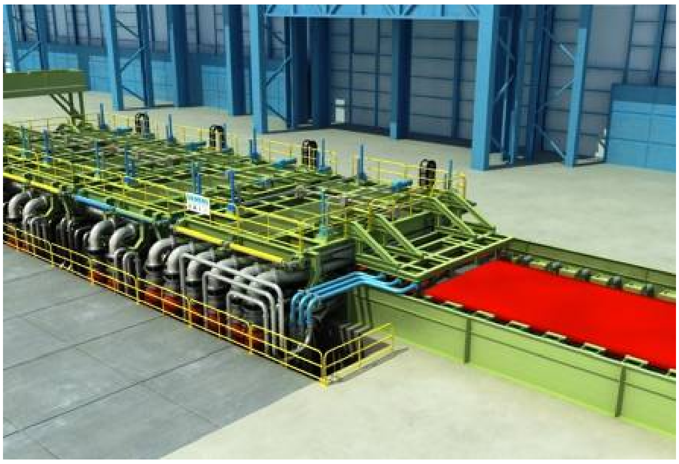

Figure 9. The MULPIC® Cooling System.

The top and bottom sections of each bank have a separate water supply. Banks B, C and D are configured such that six headers are fed from a single feed, the flow being divided equally between the headers. Bank A headers are individually supplied. In total there are 18 feeds, the design allowing flow control using either a small or large control valve. Banks B, C and D are gravity fed from tanks whilst the supply to bank A is gravity fed if accelerated cooling (AC) or pumped for direct quenching (DQ).

Cooled plates must also have uniform properties over their entire area and remain flat during and after cooling[3]. These requirements are satisfied only when the cooling of the plate is homogenous over its entire surface area. A number of techniques are used to counteract the effects that lead to inhomogeneous cooling. These include an edge mask system to avoid over cooling of the plate edges, crown valves to control the flow across the plate width and head and tail masking. During feed forward control the plate temperature prior to cooling is measured at regular intervals along its length and the flows are adjusted accordingly. Without feed forward control any variations in entry temperature will be reflected in the cooling machine exit temperature measurement. By accurately varying the machine flows as the plate is cooled the temperature non-uniformity can be reduced.

To achieve the best possible performance accurate and fast response flow control is required. The MULPIC machine includes the latest high performance flow control valves from Siemens VAI. These valves use digital closed-loop control of the valve position. Figure 10 shows the much faster response of this valve compared to a valve with a conventional electro-mechanical positioner.

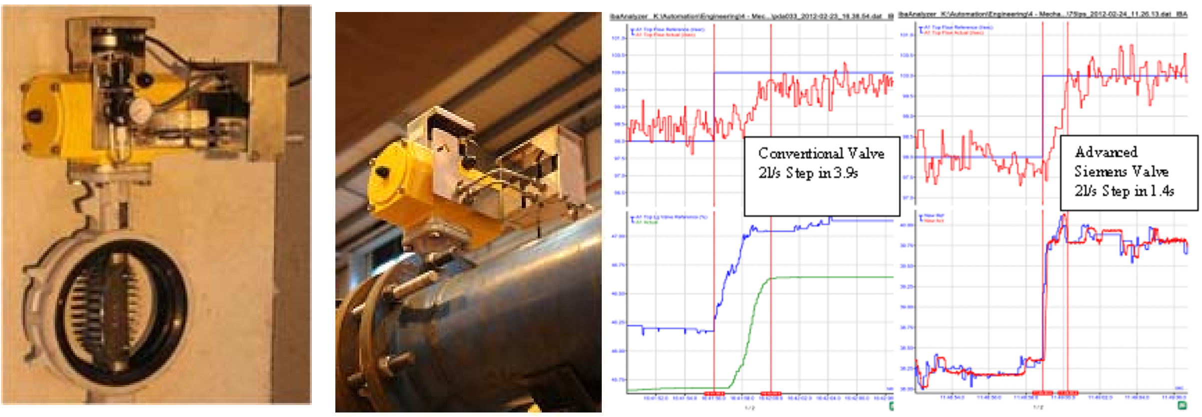

Figure 10. Siemens VAI High response flow control valve.

8 LEVELLING

Levelling is not historically considered to be a metallurgically-linked process, but since the objective is the minimisation of residual stress, and since residual stress is affected by the homogeneity of microstructure, the leveller set up would be usefully informed by a metallurgical model of the full line process. In mills rolling high-strength structural steel and abrasion-resistant grades for applications such as yellow goods, product tensile strengths can exceed 1000 MPa extending to moderate thicknesses, around 30 mm. Requirements for API-equivalent linepipe specifications above X80 and up to X120 are also driving leveller development, bringing higher loads and torques. In order to handle the high-torques the levellers are designed with individual drives for each roll.

Based on knowledge of the thickness, the width and tensile properties of the incoming plate, the levelling model computes the gaps required to reach a target plastification ratio. It also calculates the expected forces per roll, the torques per roll, and the bending necessary to compensate for the stretch of the leveller. A typical target plastification ratio lies at around 60% to 80%. This target plastification ratio value also depends on the plate data and on the incoming flatness or on parameters affecting this, such as the cooling intensity.

As a consequence of constantly increasing required duty for the leveller components, the choice for individually-driven-roll concept has become a must and was made for all of our cold and hot levellers, see Figure 11. This feature ensures reduced roll wear, reduced over torque risk, and gives a significantly higher lifetime for components such as rolls and spindles.

In order to ensure the best possible quality of the plate there is a descaling system ahead of the hot leveller.

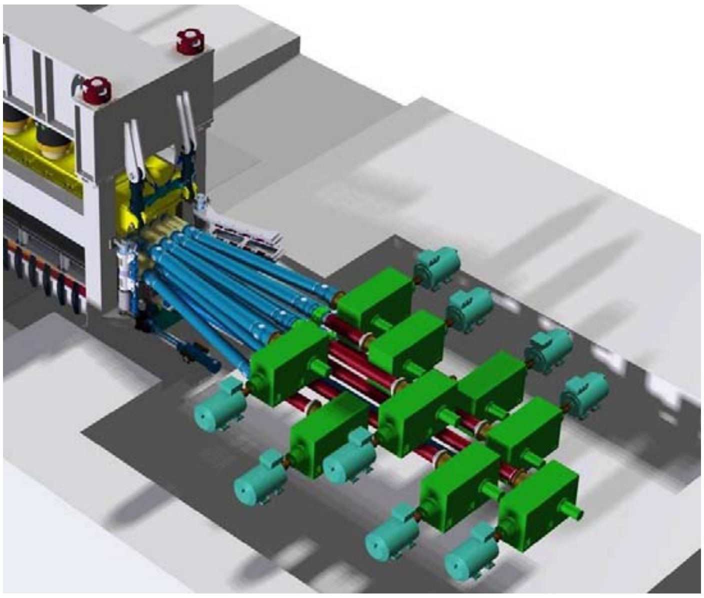

Figure 11. Leveller solution with individually driven rolls.

9 MICROSTRUCTURE MODELLING

Process knowledge has traditionally been with the plant operator. The customary approach was to specify site details that the plant builder would offer an engineering solution for. Process modelling and control systems were based on efficient commissioning. The primary measure for mill performance was accurate final dimensional tolerances. A secondary consideration was operational efficiency and the development of metallurgical properties was left to the plant operator. In the last decade, steel production and consumption has increased rapidly; a demand largely driven by developing economies. This has led to a renewed interest in plate mill installations to meet the infrastructure expansion. It has become increasingly common for plant operators to now require both equipment and a high level of process expertise from the plant builder. This has forced a change in the traditional relationship.

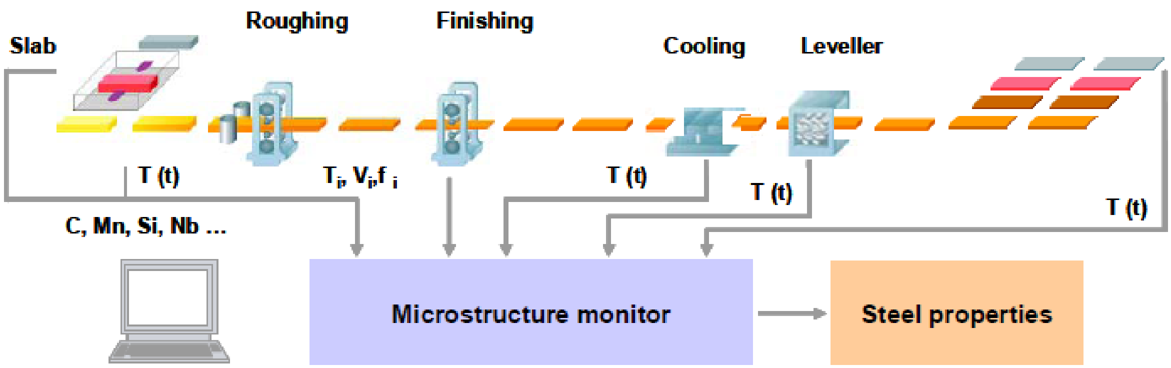

Figure 12. Process data input from existing level2 automation system to the MSM for a plate mill.

In steel production, plate processing presents the widest portfolio, but the greatest technical challenge in final property control. Part of this is due to the nature of the steel itself, which can be tailored to produce an exceptional range of final properties and applications, but also the flexibility that this plant layout offers. Microstructure modelling for steel can be traced back to the work carried out in the 1980's[4] which provides the basis for the semi-empirical physical models. In the MSM of Siemens VAI this approach has been updated and coupled to neural network models to predict the final microstructure and mechanical properties. By integrating the MSM into the core temperature model of the Siemens VAI level 2 pass schedule calculation, a real time simulation of the microstructure evolution can be provided. Surface pyrometer measurements are adapted for an essential through thickness temperature model. In comparison the microstructure model uses a volume average temperature because the final measured mechanical properties also integrate over the plate thickness. Neural networks train the models to predict mechanical properties from the chemical composition and the processing parameters.[5,6]

10 CONCLUSION

Continuous improvement of process routes along with engineering development is key to future of Plate Mill technologies. Siemens VAI is currently commissioning three major plate mills worldwide and continues to invest on innovative solutions for a sustainable future for the Plate Mill technologies.

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