SIEMENS VAI'S FULLY INTEGRATED HOT-STRIP MILL FOR THE PRODUCTION OF HIGH-STRENGTH STEEL[1]

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Abstract

On July 18, 2005 Siemens VAI received an order from Mittal Steel Poland (Mittal Steel Group) for the turnkey supply of a new high-capacity hot-strip mill in Krakow, Poland. The mill, which will be capable of rolling 2.4 million t/a of a wide range of carbon, stainless and special steel grades in widths of up to 2,100 mm, will be one of the widest hot-strip mills in Europe. Start-up is scheduled to commence in early 2007. This paper outlines the project background, scope and technological highlights of this project.

Key words: Hot-strip mill; Turnkey; Fully integrated.

LINHA DE LAMINAÇÃO A QUENTE PARA FABRICAÇÃO DE AÇOS DE ALTA RESISTÊNCIA

Abstract

Em 18 de julho de 2005 a SIEMENS VAI recebeu uma ordem da Mittal Steel Poland (Mittal Steel Group) para o fornecimento "turnkey" de uma nova linha de laminação a quente de alta capacidade em Krakow, Polônia. A usina, que vai ter capacidade para laminar 24 milhões de toneladas por ano de uma enorme gama de aços carbono, inox e aços especiais com larguras de até 2.100mm, vai ser uma das linhas de laminação a quente mais largas da Europa. "Start up" está marcado para o início de 2007. Este artigo destaca o "background" do projeto, e os destaques de tecnologia e fornecimento.

Palavras-chave: Laminação a quente; Turnkey; Fully integrated

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INTRODUCTION

With a crude steel production of approximately 7.6 million t/a Mittal Steel Poland SA is the largest integrated iron and steelmaking company in Poland. This tonnage represents approximately 70% of the entire Polish steel production. Mittal Steel Poland recently consolidated the four largest Polish steel plants located in Krakow (former Huta Sendzimira), Dabrowa Gornicza (former Huta Katowice), Sosnowiec (former Huta Cedler) and in Swietochlowice (former Huta Florian). In the course of an extensive modernization program which followed, Mittal Steel awarded Siemens VAI a contract for the turnkey supply and installation of a hot-strip mill at the Krakow steel works. This mill will have a rolling capacity of 2.4 million tons per annum of a wide range of high-quality carbon, stainless and special steel grades in thicknesses of 1.2–25.4 mm and at widths of 750–2,100 mm. This will be the first new hot-strip mill built in Europe during the past ten years.
This project is the latest in a series of orders received and implemented by Siemens VAI from this steel works, which extend back 35 years to the year 1971. The projects include the engineering LD converters, installation of a rougher and edger for a plate mill, modernization of the existing hot-strip mill, supply of a new color-coating line as well as numerous automation and process optimization projects for the coke-oven batteries, blast furnace, reheating furnace, hot-rolling mill, pickling line, cold-rolling mill, finishing lines, packaging line and section mill.

SCOPE OF PROJECT

Siemens VAI's responsibility for this turnkey project comprises the engineering, supply, installation start-up and commissioning of a complete semi-continuous ultra-wide hot-strip mill with a rolling capacity of 2.4 million t/a. The equipment supply comprises a walking-beam reheating furnace, a reversing roughing mill with attached edger, a 6-stand 4-high finishing mill with "SmartCrown®" shifting and bending technology (employing specially shaped work rolls which enhance the profile and flatness-control capability), a strip-cooling section featuring "QuickSwitch" laminar-cooling headers (allowing for a more precise cooling control—especially important for advanced steel grades), coiling section with two Siemens VAI "PowerCoilers" (with four wrapper rolls for the reliable coiling of high-strength-steel grades), all electrical and automation systems in addition to a series of advanced technological packages to assure optimized rolling operations, mill output and product quality (Figure 1). Additionally, all civil works in the existing mill bay—previously a slabbing mill—and auxiliary plants such as the roll shop and the water-treatment plant will be carried out. The project is to be carried out within an extremely tight implementation schedule. Training for operational and maintenance personnel will also be provided. The main equipment and systems to be supplied as well as the principal product data are shown in the sidebar.

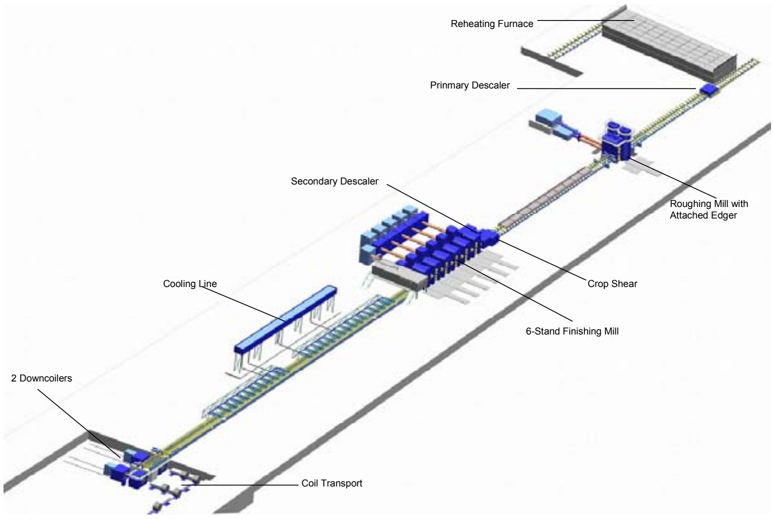

Figure 1. Layout of the Mittal Steel Poland Hot-Strip Mill

MAIN EQUIPMENT AND SYSTEMS

- Reheating furnace and slab-handling equipment
- High-pressure descaling unit
- 4-High reversing roughing mill with attached edger
- Heat-retention system (Encopanels®)
- Crop shear
- Finishing mill comprised of six 4-high finishing stands incorporating the SmartCrown® technology package
- Cooling line with QuickSwitch Cooling Headers
- Two PowerCoiler downcoilers, including coil-transport system
- Electrical equipment and automation systems, including
  - High- and medium-voltage system
  - Main and auxiliary drives, as well as associated transformers and controls
  - Low-voltage distribution and UPS (Uninterrupted Power Supply)
  - Basic automation
  - Technological control system
  - Process optimization
  - Human Machine Interface (HMI)
- Auxiliary plants and facilities, e.g., roll-shop, laboratory, water-treatment plant, electrical substation
- All civil works and building steel structures

Product Data

Capacity 2.4 million t/a
Slab thickness 220 and 250 mm
Strip thickness 1.2 – 25.4 mm
Strip width 750 – 2,100 mm
Max. coil weight Max. 35 t
Specific coil weight Max. 21.6 kg/mm
Steel Grades Structural steel, API pipe grades (X70, X80), automotive grades (DP, TRIP), HSLA grades, silicon steels (GO, GNO), austenitic and ferritic steel *

*API—American Petroleum Institute; DP—dual phase; TRIP—transformation induced plasticity; HSLA—high strength, low alloy; GO—grain oriented; GNO—grain non-oriented

Project schedule

Most of the equipment and components have already been engineered and are presently (June 2006) being manufactured. Civil works activities are in progress in the existing mill bay. Foundation for the reheating-furnace area has already been completed and the erection of the steel columns in the furnace bay started in May 2006.
Completion of plant installation is scheduled for late 2006 and the start-up of the rolling mill in early 2007. In order to minimize the start-up and commissioning period, key equipment, automation systems and technological packages will undergo extensive workshop testing prior to delivery.

Reheating furnace

Techint Italimpianti will supply a single walking-beam-type reheating furnace with a total length of 62 m with a slab-reheating capacity of maximal 450 t/h at a maximum slab-discharge temperature of 1,250 °C. An advanced furnace optimization and control system will be supplied to assure an optimized energy consumption and a maximum slab output.

Rougher with attached hydraulic edger

A 4-high reversing roughing mill will roll the reheated 220–250-mm-thick slabs to transfer-bar thicknesses between 30 and 55 mm (Figure 2). A fully hydraulic vertical edger with automatic width-control functions will be installed at the entry side of the roughing-mill housing to assure a constant width of the slab and transfer bar for an improved final strip-width distribution.

Figure 2. Analogous Roughing-Mill Photograph with Attached Edger

Roughing Stand

Type 4-High reversing stand
Roll-barrel length 2,250 mm
Max. rolling force 50,000 kN
Rated power 2 x 8,000 kW

Edger

Max. width reduction	100 mm
Slab thickness	max. 250 mm
Max. rolling force	7,000 kN
Rated power	2 x 1,500 kW

Encopanel® heat-retention system

The so-called Encopanel® heat-retention system developed by Encomech Engineering Ltd, a 100% subsidiary of Siemens VAI, will be installed after the roughing mill to conserve the heat of the transfer bars as well as enable a more accurate control of the strip temperature for quality reasons (Figure 3). This is achieved through the automatic selective raising or lowering of the heat-retention panels. This solution allows, for example, the strip-edge temperatures to be maintained at a higher temperature for rolling in the finishing mill, thereby avoiding edge cracking. As a special feature, bottom-scale clearing panels will be mounted on specially designed carry-over bars which oscillate to ensure that scale is discharged from the system to ensure a scale-free Encopanel® face to the transfer bar.

Figure 3. Encopanel® Heat-Retention System

Now applied in over 20 hot-strip mills, Encopanels® are the leading heat-retention system installed worldwide. Application of the Encopanel® system will reduce greenhouse gas emissions in that the fuel requirements of the reheating furnace and the electrical power requirements of the finishing mill will be reduced.

Type:	Passive heat-retention system
Total Length	72 m
Number of modules	16
Heat retention	Passive (no additional heating)
Transfer-bar thickness	Min. 30 mm, max. 55 mm

Heavy crop shear

A heavy-duty crop shear will be installed after the Encopanels® and will be capable of cutting transfer-bar thicknesses from 30–55 mm, including API steel grades (e.g., X80 with a maximum dimension of 55 mm x 2150 mm).
Highly accurate cutting will be assured by a special crop-optimization system based on the use of an infrared shape camera positioned behind the Encopanels® which measures the shape of the transfer bar head/tail and calculates the necessary crop-cut length. A speed gauge located in front of the crop shear determines the optimum cutting point for the shear. The system also allows fixed-length crop cuts as well as manual operator override.

Finishing mill

The finishing mill will be equipped with the latest technological features and automation systems as required for a high-performance mill of this type (Figure 4).

Figure 4. Design of the Finishing Mill for Mittal Steel Poland, Krakow

Type	Six 4-high stands
Work-roll-barrel length	2,500 mm
Max. rolling force	45,000 kN
	Rated power 10 MW each

In particular the SmartCrown® technology package will ensure that highly rigid standards for strip profile and flatness control will be met. The components and systems of this package include:

- ♦ SmartCrown® work-roll contour
- ♦ L-type bending and shifting block
- ♦ Roll-stack deformation model
- ♦ Thermal crown and wear model

SmartCrown® Work-Roll Contour

The SmartCrown® work-roll contour is a new solution for strip profile and flatness control, enabling tighter tolerance values and reduced off-gauge strip lengths. The roll contour itself can be described as a sum of a sinusoidal and a linear function which results in an unloaded roll-gap profile which is always cosine-shaped. With the use of a sophisticated profile and flatness model the SmartCrown® work rolls are shifted to adjust the roll-gap contour to obtain the desired strip profile or to match the roll contour to the crown of the incoming strip (Figure 5).

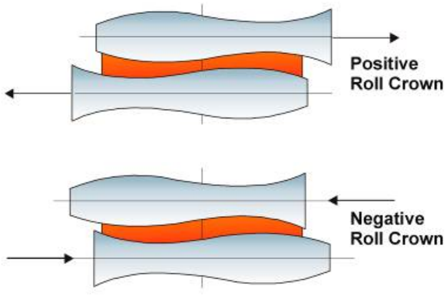

Figure 5. SmartCrown® Work-Roll Contour and Operating Principle

Rolling with SmartCrown® work-rolls is normally carried out in combination with work-roll bending. The principal features and benefits of this solution can be summarized as follows:

- Significantly enhanced profile and flatness control range in comparison with standard work-roll bending
- Need for only one single roll contour (per rolling stand), dispensing with the need for frequent roll changes to roll different strip profiles
- Increased flexibility in the rolling program and pass schedule for improved utilization of the mill capacity
- Simple mechanical design based on use of standard hydraulic cylinders
- Avoidance of quarter buckles through local thickness reductions in quarter-buckle-sensitive areas (lower longitudinal compressive forces in strip)
- Application of a sophisticated profile and flatness model to assure that the final strip profile and flatness results are within tight dimensional tolerances

Profile and Flatness Model

The aim of the profile- and flatness-control strategy is to establish a certain roll-gap shape for each stand with the use of the roll-gap actuators (work-roll bending and shifting with or without SmartCrown®). The roll-gap shape is calculated taking into consideration the material cross flow, which is high in the first stands of the finishing mill and close to zero in the final stands. For the calculation of the best profile and flatness setup, a cost-optimization function- is chosen, using a powerful mathematical algorithm. The advantage of the mathematical optimization approach is that it is relatively simple to account for different types of restrictions for the setup values of the shifting position and bending forces of the six finishing stands.

L-Type Bending Block

A new L-Block system for positive work-roll bending, which can operate in conjunction with the SmartCrown® work-roll contour, was developed by Siemens VAI to reduce mill stand investment costs and maintenance downtime. Characterized by its simplified design, the system operates on the basis of moveable L-shaped structures, which are guided inside the unit housing in the vertical direction to exert pressure on the work-roll chocks (Figure 6). During work-roll shifting, the work-roll chocks, which support the work rolls, are shifted together with the work rolls in the lateral direction while the L-Block remains in a stationary position. This design solution offers the advantage of a reduced bearing play which results in a more exact adjustment capability of the work rolls. In addition to the cited benefits, the necessary time for work-roll changes is shortened, again reducing overall mill downtime.

Figure 6. L-Shaped Structures of the L-Type Bending Block for Roll Bending

Roll-Stack Deformation Model

The exact calculation of the shape of the loaded roll gap is a decisive factor for proper profile and flatness control by the process-optimization system. This is made possible through the application of a new roll-stack deformation model, which is a fully 3-D elasticity model that takes into consideration the real geometry of the roll barrel and necks, the applied roll- and bending forces as well as the real pressure distribution between work- and back-up rolls. With the same accuracy as time-consuming 3-D finite-element computations, the roll-stack deformation model can perform the required calculations within milliseconds, allowing the necessary roll-gap adjustments to be instantly executed, particularly for the incoming strip-head ends.

Thermal Crown and Wear Model

The real-time and fully 3-D calculation of the thermal crown and wear to determine the precise roll shape is a necessary data input for the roll-stack deformation model. The thermal crown model keeps track of the thermal expansion and contraction of the work rolls on the basis of the calculated rise and drop of the work-roll temperature. The work-roll temperature distribution is recalculated cyclically on the basis of a three-dimensional, rotational symmetric heat equation. The model considers effects such as the temperature increase due to heat flow from rolled material to the work roll, the temperature drop due to heat flow from the work roll to the coolant of the cooling system, and the temperature drop due to the heat flow from the work roll to the surrounding air.

Feed-Forward Control

Deviations in the thickness of the hot-rolled material are caused by a variety of factors. These can be thickness deviations present in the incoming strip as well as thickness deviations which arise during rolling as a result of temperature variations present in the strip from, for example, skid marks from the reheating furnace. The objective of the feed-forward control system is to identify thickness and temperature deviations in the intermediate sections of the finishing mill, where usually no thickness and temperature measurements are possible. With the application of a Kalman Estimator such deviations can be identified and correction values applied at the downstream mill stands to achieve the narrowest thickness tolerance values at the centerline of the rolled strip.

Cooling section

In the cooling section after the finishing mill QuickSwitch Cooling Headers will be installed to reduce the time required for on/off water-flow operations to less than one second. In conventional cooling headers on/off operations typically require several seconds for completion, making an accurate control of the coiling temperature of the strip difficult. With the QuickSwitch Cooling Header solution the water flow is immediately laminar and, in combination with a hot-strip cooling model, the accuracy of the coiling temperature can be improved (Figure 7).

Figure 7. Example of a QuickSwitch Cooling Header

On the basis of temperature measurements conducted after the finishing mill, at intermediate positions in the cooling section, and immediately prior to the downcoilers, the cooling model provides a precise cooling-strategy set-up tailored to the steel grades being rolled and their respective rolling parameters. High and reproducible strip-quality will be achieved along the entire strip length, for the strip head and tail ends.

Coiling

In the coiling section two so-called PowerCoilers will be installed at the end of the Krakow hot-strip mill to allow for an improved coiling of high-strength and other advanced steel grades, especially for thicker gauges (Figure 8). A key focus of this development was to employ the pinch rolls and the first wrapper-roll unit to prebend the incoming strip so that the overall power demands for the initial coil windings could be significantly reduced with a simultaneous reduction of friction between the strip and coiler aprons. The special features of this coiling unit include:

- ♦ Incorporation of a fully hydraulic and improved pinch roll with high-speed position and pressure control
- ♦ Design of 1st wrapper roll as a twin-type unit
- ♦ Application of precise force control on first wrapper-roll unit
- ♦ Installation of a 4th wrapper roll and correspondingly shorter apron lengths for reduced friction with incoming strip

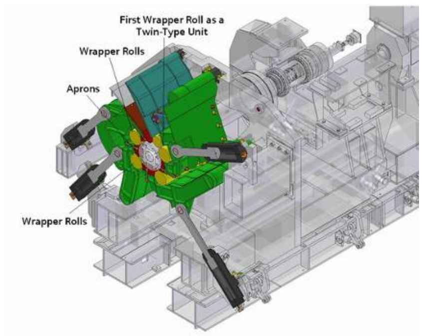

Figure 8. Design of PowerCoiler

Advanced control systems will be installed to enable dynamic step-control and force control of the wrapper rolls, non-linear hydraulic gap-adjustments, hydraulic pinch-roll control, hydraulic side-guide control and strip-tension control. Other features, such as variable pinch-roll forces as a function of the amount of coiled strip, side-guide force control and oscillation-function, as well as tracked tension relief during strip thread-out from the finishing mill will also contribute to the strip-coiling quality with respect to telescopy. The key advantages of the PowerCoiler solution include a significantly lower power consumption required for coiling, improved strip threading, more compact coiling—especially for thick-gauge, high-strength steels—and significantly reduced strip slippage and scratching.

Automation and electrical systems

A completely new high-voltage power-distribution system connected to the 110 kV overhead supply line will be provided. The 30 kV and a 6 kV sub-distribution, including power-factor-compensation equipment, will be distributed to the consumer locations and according to the process requirements in such a way as to minimize cable lengths and power losses.
For the main drives of the roughing mill and the finishing mill multi-level voltage-source converters (Simovert ML2), together with non-salient-pole synchronous motors, will be supplied. An IGBT LV Voltage Source Converter (VSC) system will be supplied for the edger drives, downcoiler drives and crop shear (Figure 9).

Figure 9. Analogous Photograph of a Siemens Main Drive for a Hot-Strip Mill

To assure excellent dimensional properties of the strip, a process-optimization system will be provided which will include dynamic models for the pass-schedule calculation, physical sub-models for computing product and mill behavior for the pass-schedule calculation, a roll-stack deformation model, a thermal crown and roll-wear model, a profile and flatness model, a laminar-cooling model as well as quality-data evaluation, reporting and operator interface functions.
The supplied technological control systems will assure fulfillment of the tightest material tolerances, including automatic width control, automatic gap control for the roughing mill and finishing mill, main drive speed set-point calculation, looper height and tension control, automatic profile and flatness control, downcoiler side guide, pinch roll and wrapper-roll control.
The basic automation system will include sequence and movement control for the slab transportation, roughing mill, Encopanel® control, crop-optimization system, crop-shear control, automatic work-roll change for the finishing mill, a gauging system for exact dimensional measurements of the material, downcoiler control, alarm and event handling as well as a powerful HMI for the operator.
Prior to the shipment of the automation system to the plant site extensive testing will be performed. After the functions of each individual automation system have been tested, the components of the process control and optimization systems, HMI, control desks, etc., will be assembled and connected in one of the Siemens VAI test labs to perform a “system test.” The target of this test is to check the entire automation system under conditions close to the later operational configuration of the equipment.

The test will help to check the behavior of the entire automation system already before start-up, to recognize and eliminate errors related to the interaction of the involved automation systems, as well as to speed up the system start-up and reduce the overall duration of commissioning.

CONCLUDING REMARKS

With the completion of this hot-rolling mill project scheduled for 2007, Mittal Steel Poland, Krakow will be able to roll a wide range of high-quality steel grades which will find use in the domestic and international markets. With the mill's capability to roll strip in widths of up to 2,100 mm, this will open up new market opportunities for the company, especially in the high-quality product sector.
This project is an excellent example of the turnkey supply capability of Siemens VAI, showing the full range of design solutions, technologies, systems and services that can be offered from a single group of companies.