OVERVIEW ON THE LATEST EUROPEAN INSTALLATIONS OF TANDEM COLD MILLS[1]

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Abstract
The technological and process automation experience of Siemens VAI in modern tandem cold mill installations are represented by the two latest installations of such mills in Europe. Both Voestalpine Stahl in Austria and Corus in the Netherlands are leading steel suppliers which are supplying high quality products to e.g. the automotive industry. Both lines are as well dedicated to the production of advanced high strength steel grades such as dual phase steels. The new mills meet the highest quality standards in terms of strip flatness, strip surface, strip cleanliness, dimensional tolerances and strip roughness. Specific design and automation solutions had to be implemented to cover the production of hard materials. Specific features such as a skin-pass rolling mode were installed. Both mills run on the most modern drive and automation solutions. The paper will include operational results of the start up of the mills and describe the implemented safety solutions.
Key words: Continuous tandem cold mills; Cold-rolling; AHSS; SIROLLCIS CM.

PANORAMA DAS MAIS RECENTES INSTALAÇÕES EUROPÉIAS DE TRENS LAMINADORES A FRIO

Resumo
A experiência tecnológica e de automação de processo da Siemens VAI em laminações contínuas a frio é representada pelas duas mais recentes instalações deste tipo na Europa. Tanto a austríaca Voestalpine Stahl com a holandesa Corus são siderúrgicas líderes no fornecimento de produtos de alta qualidade para, por exemplo, a indústria automobilística. Ambas as linhas são dedicadas também à produção de qualidades avançadas de aços de alta resistência, como os aços de fase dupla.Os novos laminadores atendem aos mais altos padrões de qualidade em termos de planura, condição superficial, limpeza, tolerâncias dimensionais e rugosidade da tira. Soluções de projeto e automação específicas tiveram que ser implementadas para atender a produção de materiais de alta dureza. Características específicas, tais como o modo de laminação de encruamento, também foram instaladas.Ambos os laminadores operam com as mais modernas soluções de automação e acionamento. Este artigo mostrará também resultados operacionais do início de operação dos laminadores e descreverá as soluções de segurança implementadas.
Palavras-chave: Trens laminadores a frio; AHSS; SIROLLCIS CM

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Introduction

The technological and process automation experience of Siemens VAI in modern tandem cold mill installations are represented by the two latest installations of such mills in Europe. Both voestalpine Stahl in Austria and Corus in the Netherlands are leading steel suppliers which are supplying high-quality products to e.g. the automotive industry. Both lines are as well dedicated to the production of advanced high-strength steel grades such as dual phase steels. The new mills meet the highest quality standards in terms of strip flatness, strip surface, strip cleanliness, dimensional tolerances and strip roughness. Specific design and automation solutions had to be implemented to cover the production of hard materials. Specific features such as a skin-pass rolling mode were installed.
Both mills run on the most modern drive and automation solutions.

Continuous Tandem Cold Mill for voestalpine Stahl, Linz, Austria

The new continuous tandem cold mill of voestalpine Stahl Linz in Austria is designed to mainly produce advanced high-strength steel grades which are deter-mined for the automobile industry. The mill layout allows the additional installation of a pickling section and thus the extension to a full coupled pickling line and tandem cold mill (PLTCM). The mill concept is based on 4-high technology. Siemens VAI installed high sophisticated technical solutions and in conjunction with the high grade of automation the highest mill availability and energy optimization can be reached.

Layout, product mix and plant data

An L-type layout was found to be the optimum solution according to the available place in the existing integrated steel works in Linz. The strip is diverted by a helical turn device in an angle of 90°, the strip sides are turned at the same time.
The mill consists of the entry coil handling including automatic debanding machine, pay-off reel, laser welder, looper, tandem mill, two tension reels, an inline inspection station and exit coil handling equipment (automatic marking, banding, coil eye welding). The Siemens VAI scope of supplies and services includes mechanical equipment, hydraulic and pneumatic systems all drive systems, electrics and automation, safety equipment, erection, installation and commissioning. The whole production line (Figure 2) is designed for a future extension to a coupled pickling line and tandem cold mill (PLTCM).

Table 1. Product mix

DP, TRIP, MP (up to tensile strength of 1,300 MPa)	400,000 t/a
HSLA, HS-IF, structural, CM, C steel	671,000 t/a
Si steel	90,000 t/a
IF steel	59,000 t/a
Total production	1,220,000 t/a

Figure 1: Cont. tandem cold mill, voestalpine Stahl, Austria

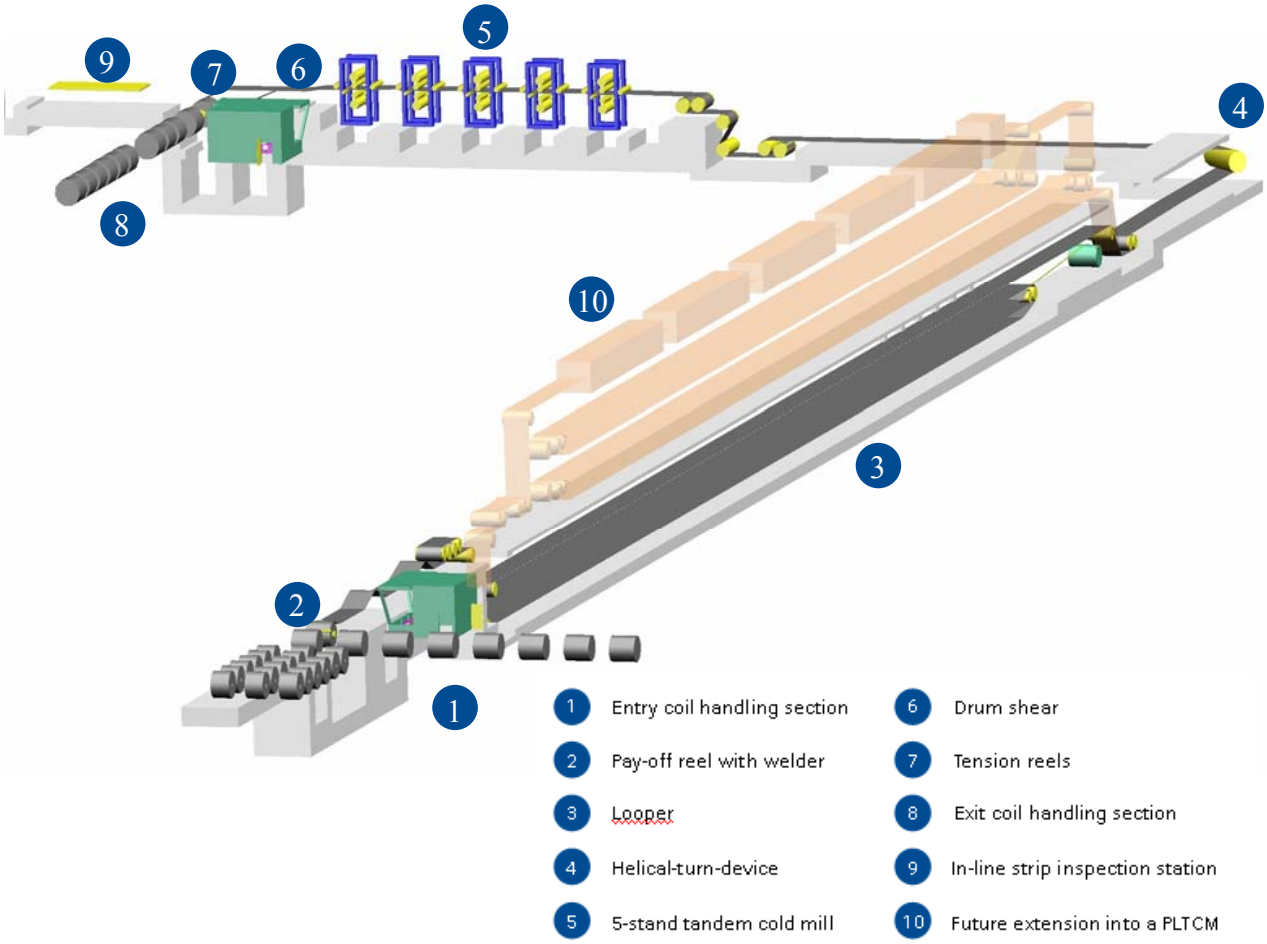

Figure 2: Layout of the continuous tandem cold mill of voestalpine Stahl, Austria

Table 2. Plant data

Mill characteristics		Mill speeds	
Mill type	5-stand, 4-high	Pay-off reel	max. 500 m/min
Roll separating force per stand	35,000 kN	Entry cutting	max. 60 m/min
		Entry tandem mill	max. 400 m/min
Work-roll bending force	max. 1,200 kN	Exit tandem mill	max. 1,000 m/min
Work-roll shifting stroke	± 105 mm		
Work-roll crown	SIROLLCIS Smartcrown®		
Drive power per mill stand	2 x 3,000 kW		
Drive power tension reel	2,070 kW		
Strip dimensions		Strip surface	O3, automobile O5
Entry thickness	2.0–6.0 mm		
Exit thickness	0.35–3.0 mm		
Strip width	700–1,750 mm		
Coil weight	max. 35 t		

Specific requirements for AHSS production

From the very beginning of the planning phase voestalpine was investigating 4 and 6-high solutions for their rolling mill. Beside the good flatness performance voestalpine expected additionally extremely tough thickness performance. To provide the best possible support for thickness control (HAGC), the mill stands should therefore preferably be designed as stiff as possible to fulfill this demand. A comparison of the mill stretch for the same strip rolled in a 4-high and 6-high mill stand shows that the total stiffness of a 4-high mill stand (5.4 MN/mm) is about one third larger than for a 6-high mill stand (4.0 MN/mm), which positively affects the thickness-control performance. The main reasons for the higher stiffness of a 4-high mill stand are the shorter oil column in the adjusting cylinder and the avoidance of flattening of the intermediate rolls. Based on this technical evaluation and benchmarking of 6-high and 4-high mills voestalpine decided for the installation of a tandem mill based on 4-high technology. The benchmarking considered operational cost (esp. investment cost for rolls and according equipment, inventory cost, roll grinding cost, etc.), thickness and flatness performance, surface quality and the capability to roll hard AHSS grades.
To ensure optimum rolling conditions special attention was turned on the emulsion system including the vacuum vaporization. The saponification value of the rolling oil was optimized during commissioning and increased significantly to ensure optimum roll gap lubrication conditions.

Figure 3: Tandem cold mill – mill windows

Drive system

The main and auxiliary drives, in combination with the mill stands, play a key role in the success of a continuous tandem cold mill. When it comes to final strip quality, the performance of a multi-stand mill depends substantially on the main drives. For the drive systems at voestalpine the completely new SIROLLCIS Sinamics SM150 and S120 family has been applied. Based on a single platform, our SI-ROLLCIS Sinamics drives combine to form a complete and consistent drive family that spans the entire performance range with regard to flexibility, functionality and engineering design. The SM150 uses low to high-speed applications with regenerative supply. This requires high output power, torque and dynamic response. These IGCT (Integrated Gate Commutated Thyristor) technology-based medium-voltage source converters are applied in the main motors of the mill stands. These compact and reliable systems feature quiet operation and excellent dynamic response.
The modular design and high performance of the SIROLLCIS Sinamics S120 IGBT (Insulated Gate Bipolar Thyristor) low-voltage converters are installed for the drives of bridles, pumps and coilers.

Figure 4: Pulpit and work-roll changing car

SIROLLCIS CM completely integrated solution

The automation solution is based on SIROLLCIS Simatic PCS7 as the standard engineering and control system for plant operation and fault diagnosis.
The entire automation is based on the high performance SIROLLCIS Simatic TDC automation system provides maximum computing power for sequence and technological controls. All process peripheral equipment is connected via ET200 distributed I/Os.
An open communication system allows the data exchanges between the different automation tasks, using the Fast Ethernet bus as the process bus, SIROLLCIS Simatic TDC global data memory for real-time data exchange between the system controls, Profi-bus as field bus for peripheral equipment. SIROLLCIS Simatic WinCC is used as plant-wide visualization system, which features central power-up capability, central message and diagnostic system which can be operated from any plant monitor.
The plant relies on the highly successful Siemens VAI thickness control concept which uses the extended mass-flow technique to ensure tight tolerances under all operational conditions. This concept controls reduction at the individual stands, decouples the stands by means of strip-tension controllers, and achieves with this means very close strip gauge tolerances. The flying gauge change automatic is

included to minimize the off-gauge length. The flatness control system behind stands no. 1, 3 and 5 makes use of neural networks that have a self-learning function, enabling the precise adaption to production requirements.
The Industrial PC based process automation system (level 2) includes auto-adaptive process models based on advanced physical models and neuronal network for optimization. An ideal combination of physical models and auto-adaptive algorithms is the key to success in process modeling. For the flexible operation of high-performance continuous tandem cold mills, following functionalities are implemented in the level 2 system:
- Speed optimization
- Coil building
- Interfacing to level 3
- Production planning
- Quality data evaluation

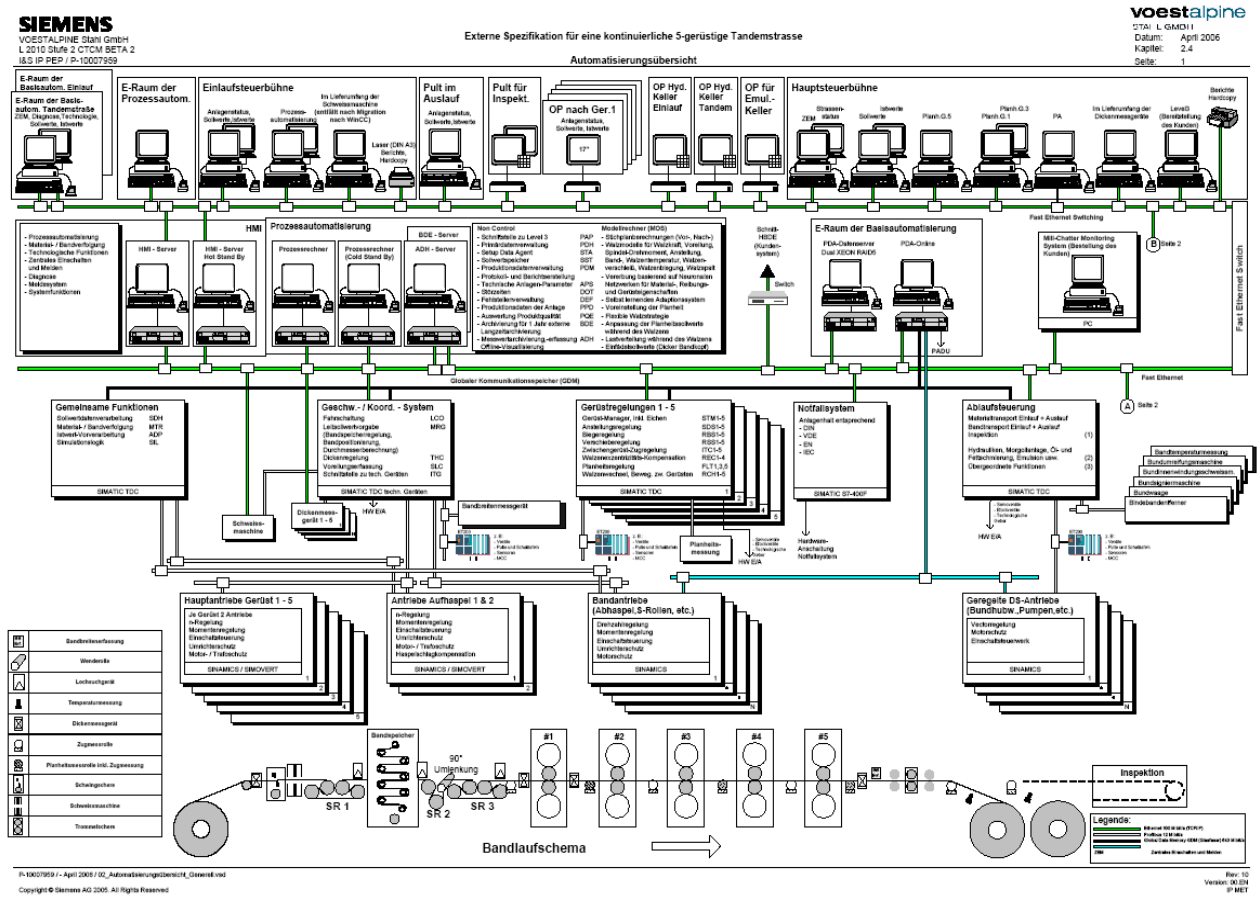

Figure 5: Automation overview - New tandem cold mill - voestalpine Stahl, Austria

Integration test for automation and drive system

For voestalpine Stahl Siemens VAI thoroughly tested the complete automation system, including all visualization systems, control consoles and the drive systems in the test facilities in Erlangen, Germany before shipment.

Figure 6: Integration test at the test facilities in Erlangen, Germany

Safety

Safety areas were defined to avoid any negative impact for the operation and were partly divided into sections to be able to recover malfunctions during operation. It is for example possible to enter the safety area of the entry and exit coil transport without stopping the whole line. Specific areas were designed to enable changing or set-up procedures e.g. change of binding strip in the coil binding area during normal operation. The fully automatic roll change system is safety related designed that during an ongoing roll change the area is allowed to be entered if any malfunction of the roll change car occurs. The mechanical and electrical equipment in combination with a detailed risk analysis meet the highest European machine directive standards.
For the realization of the safety functionality the SIROLLCIS Simatic S7 400F system is used. The Simatic S7 400F provides maximum computing power for all safety control functions. Most process peripheral equipment is connected via the ET200 failsafe remote I/O. The system is TÜV certified and used in combination with the Sinamics save torque off function without any hardware disconnector switch. SIROLLCIS CM automation system enables single-operator control.

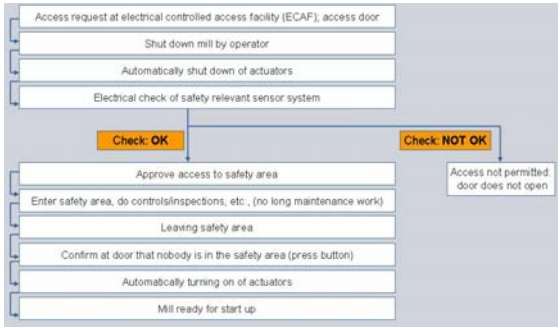

Figure 7: Safety concept

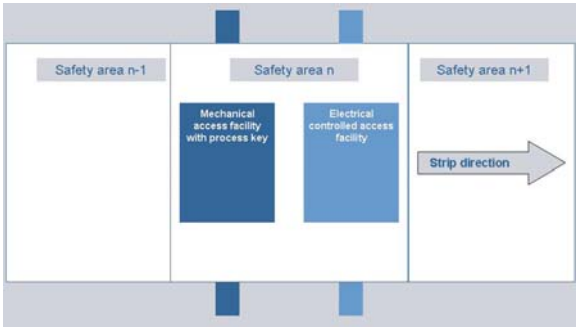

Figure 8: Safety area

Siemens VAI paid particular attention to the design of the continuous tandem cold mill's main control pulpit. The high degree of automation in all operating modes allows a single operator to control the intermediate section, the tandem cold mill and tension reels, up to the removal of the coil from the line. The intelligent diagnostic and alarm system gives the operator all relevant information in an easily understandable form, allowing quick response to changing situations. The intelligent diagnostic and alarm system enables the operator to pre-diagnose problems fast without involvement of maintenance personnel.

Thickness performance

The expected thickness quality results were reached from the very first coil according to the hydraulic AGC cylinder system and the advanced control system.

Figure 9: AGC cylinder

Flatness performance

Again the very compact and stiff mill design supports the target of achieving good flatness performance. Work-roll bending and shifting (Figure 13) based on the Smartcrown® work rolls, together with a highly efficient multi-zone cooling system, a measurement principle based on three flatness measurements and a highly sophisticated flatness control allows flatness results which are often below 4 I-Units (Figure 14).

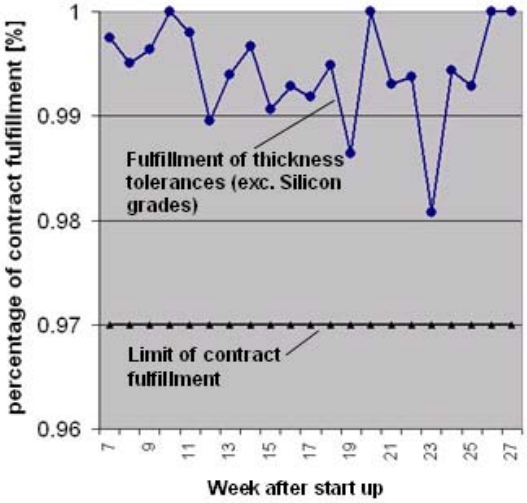

Figure 10: Thickness performance after stand no. 5 (values on a weekly basis)

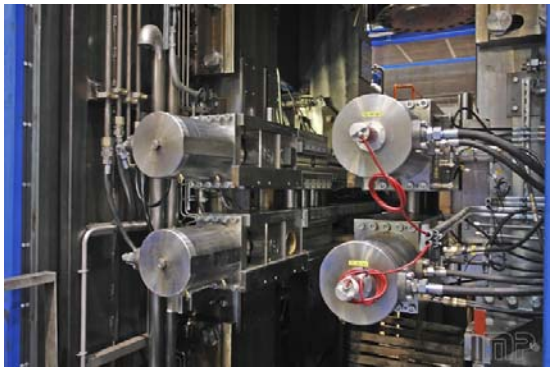

Figure 11: Work-roll shifting system

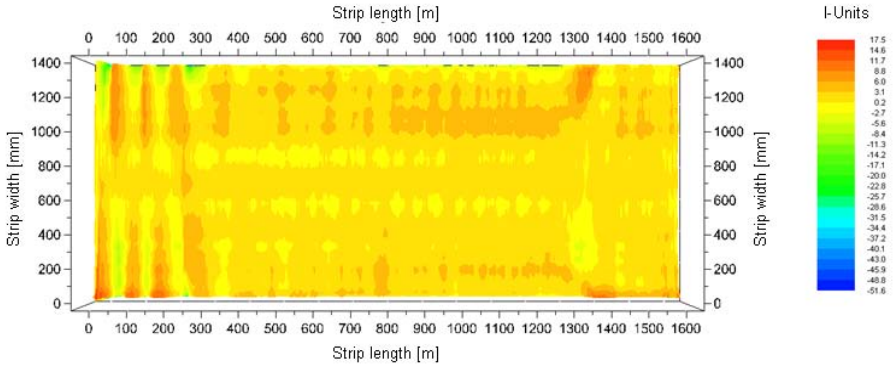

Figure 12: Typical flatness screen (flatness (4)-average value)

Strip surface quality

A number of measures support the target for a high-quality level of the strip surface and strip cleanliness. A minimum of rolls, which are in contact with the strip, were installed and the speed of all these rolls is synchronized with the strip speed to avoid any slipping that can cause scratches. A highly efficient blow-off system was installed to ensure the removal of emulsion. A highly automated inspection station (Figure 13) allows to visually inspecting strip samples of about
8 m length. A special clamping device allows turning the strip without touching it with any other tools and influencing such the surface appearance. A movable platform allows the inspector to look from a very close distance onto the strip. Strip roughness and cleanliness tests are performed and small surface defects can be detected immediately. This visual inspection can lead to roll changes and avoid that additional strips with similar surface defects are produced.

Figure 13: Inside the in-line strip inspection station

New tandem cold mill coupled to a pickling line at Corus, IJmuiden, Netherlands
Beginning of 2000, Corus Strip Product IJmuiden developed the plan for an additional production facility for cold rolled product in its integrated plant of IJmuiden, the Netherlands. Common work with Siemens VAI has been done during nearly two years to define the optimum solution within the assigned budget investment taking into account the requirement of the plant in IJmuiden, the wide product mix and specific market demand in terms of specific strip profile, a wide range of product to be process, a compact layout and optimum investment and production cost.

Figure 14: CM22 during erection at CORUS IJmuiden, The Netherlands

In July 2006 CORUS made decision in favor of Siemens VAI 6-high technology and awarded the contract to Siemens VAI for the supply as process turnkey project of the new Cold Mill 22 for production of cold rolled strip up to 1,650 mm wide. The contract also includes an automotive continuous galvanizing line for wide strip.

Layout, product mix and plant data

The new mill has been installed in the alignment of the existing pickling line assuming the length was limited to the integration in the existing plant. Possibility has been kept to use the pickling line alone to produce pickled and oiled coil when necessary. The line consists of the entry coil handling including automatic debanding machine, pay-off reel, laser welder, entry looper, process section, intermediate looper, side trimming section, coupling looper, diverting station to choose between coupled or uncoupled mode, tandem mill, one automatic inspection system SIROLLCIS Sias, one carrousel tension reel, an off-line inspection station and exit coil handling equipment (automatic marking, banding, coil eye welding). The Siemens VAI scope of supplies and services includes mechanical equipment, hydraulic and pneumatic systems all drive systems, electrics and automation, safety equipment, erection, installation and commissioning for the coupling and tandem mill area. Up-grades have been carried out on the pickling line to fit with the new requirement of the PLTCM22 (re-engineering of the automation system, improvement of entry down time, adjustment of tension map).

Table 3. Product mix

IF (DX56, DX57)	
CQ, DQ	
HSS, DP (600 to 1000)	
Annual rolling capacity	1,600,000 t/a

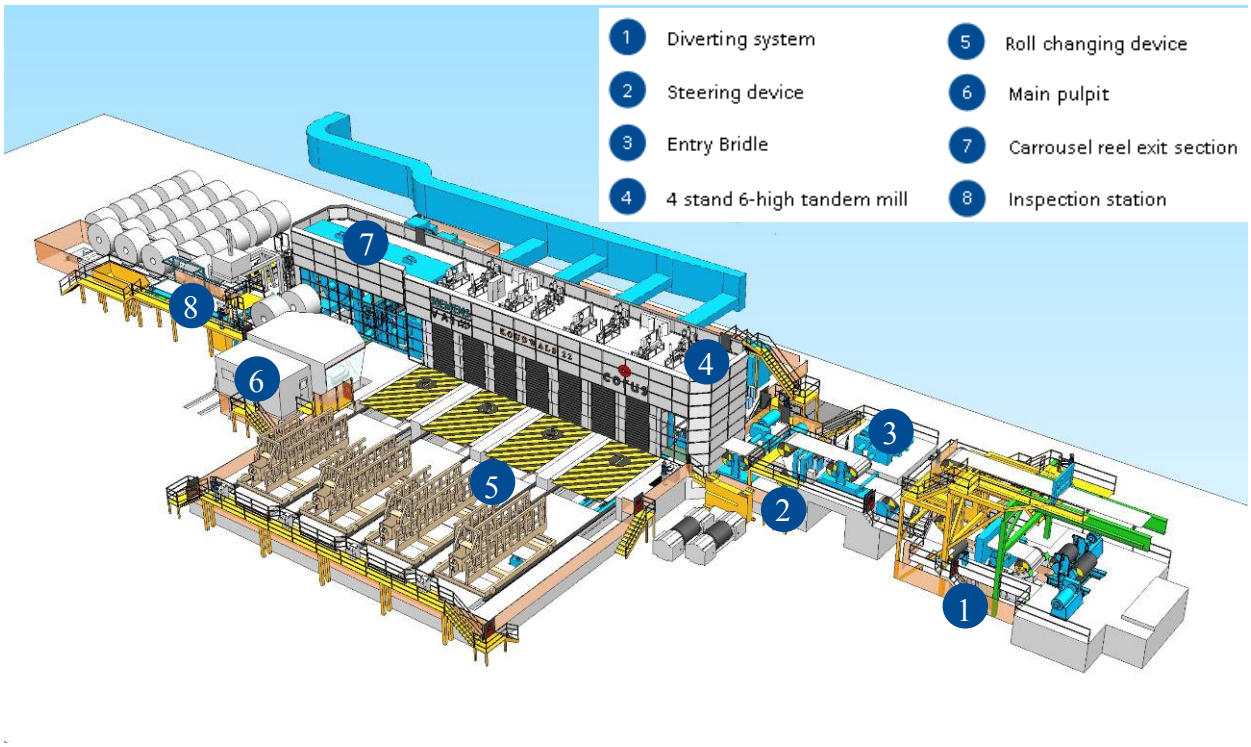

Figure 15: Layout of the tandem cold mill 22 of CORUS IJmuiden,

The Netherlands

Plant data

Mill characteristics	
Mill type	4-stand, 6-high
Roll separating force per stand	25,000 kN
Work-roll bending force	max. 1,400 kN
Intermediate-roll bending force	max. 1,400 kN
Intermediate-roll shifting stroke	550 mm
Drive power per mill stand	6,000 kW
Drive power tension reel	2,300 kW
Strip dimensions	
Entry thickness	1.0–4.0 mm
Exit thickness	0.4–3.0 mm
Strip width	700–1,650 mm
Coil weight	max. 48 t

Mill speeds	
Pay-off reel	max. 650 m/min
Process speed	400 m/min
Entry tandem mill	max. 485 m/min
Exit tandem cutting speed	300 m/min
Exit tandem mill	max. 1,200 m/min

Specific requirements for CM22

One of the most important goals of the new line was to process a wide range of products in terms of hot coil, rolling process or grades. For most of the production, the material is coming from the DSP (Direct Strip Production) route with a very specific strip shape and a low crown profile. High ability to control the strip and roll bite was one key point of the new tool. A second point was to improve the serviceability of CORUS and supply stability by being able to process a portion of the production of the existing mill CM21 if required. The mill is dedicated to automotive grades and has the capability to roll HSS steel grades. An additional requirement was to produce thin pickled and oiled strip with specific roughness on the PLTCM22. A specific skin-pass mode was implemented to address this specific process. The solution to fulfill all the requirements is a highly powered 4-stand 6-high tandem cold mill. Extended action and comprehensive operation of the edge orientated shifting strategy of the 6-high mill ensure the optimum control of the roll gap and enhanced

flatness quality. Coiling section is equipped with rotary shear and carrousel coiler which give the advantage of a compact layout and identical coiling conditions for all coils. In addition the mill exit is equipped with an SI-ROLLCIS Sias automatic strip inspection system for immediate detection of surface defect and an oiling machine for the production of skin-passed coils.

Pickling and coupling section

The pickling layout and operating parameters of the existing pickling line did not suit with the performance and operation principle required for a state of the art PLTCM. A survey has been carried out to detect the bottle neck of the line in the new configuration. Long entry down time, insufficient tension at line exit and low software maintainability have been identified as weak points of the existing pickling line. Those points have been improved to ensure the performance level of the pickling line is adequate with that of the tandem mill. The necessary equipment to couple the pickling line with the TCM was installed.

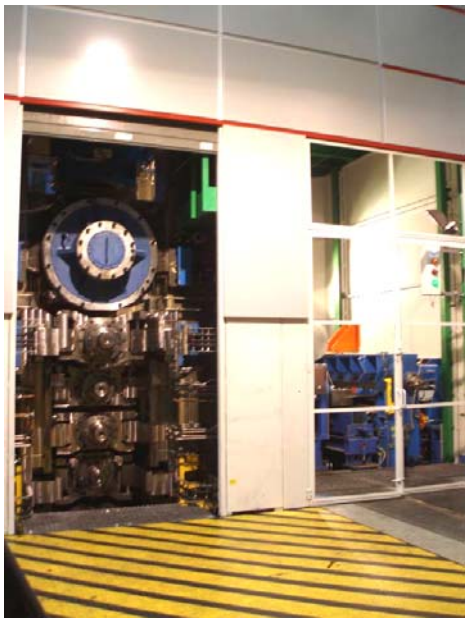

Figure 16: Tandem cold mill – mill window

Tandem mill features

From coupling looper, the strip passes through 2 steering units and two tension bridle units, last one located just before mill stand no 1. This arrangement allows a very precise strip centering and optimum response in tension control at mill stand entry giving advantage for the patented advance mass flow thickness control. The mill stands are of 6-high type with long stroke shifting of the intermediate roll. Having a flat roll force distribution on the complete strip width is clear ad-vantage to result in a low edge profile and to reach effective flatness control. The powerful bending systems for work rolls and intermediate rolls (up 70 t per side) are always working in their optimum range. Roll force, for a total of 2,500 tons per mill stand, is generated through a low hysteresis hydraulic capsule.

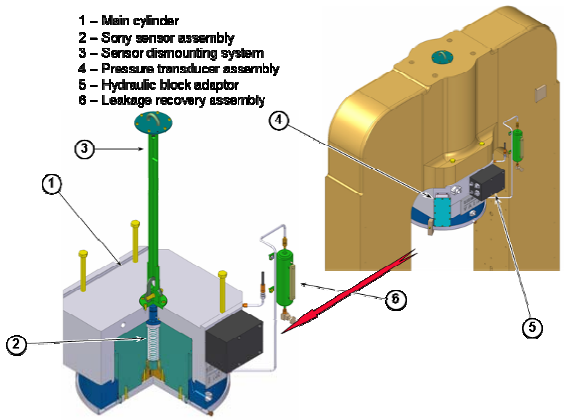

Figure 17: Hydraulic roll force cylinder principle

To ensure and control strip quality performance, speed, thickness and tension measurement have been installed at mill entry and in the Interstand areas. Instrumentation is suitable be used either during rolling operation but also during skin-passing operation with specific requirements in terms of speed and tension control for precise control of elongation and roughness transfer. State of the art recirculation emulsion system type with two tanks has been in-stalled. One tank can feed the first three stands or all stands with emulsion de-pending on the product. The second tank is dedicated to the last stand only to ensure strip cleanliness. Provision has been made to install two other tanks for the use of emulsion with higher lubricant properties to improve rolling process of next generation of HSS steel. As skin passing and rolling operation, including automotive production, takes place, highest level of cleanliness inside the mill has to be maintained. To fulfill this requirement a complete mill washing system is installed including classical high pressure fire hose but also automatic cleaning nozzles in the mill stand. To avoid any strip contamination during dry-skin passing, all the roll cooling headers are air purged.

Mill exit section

With a high target of strip quality and improved operating cost, the totality of the strip surface, top and bottom, is inspected by the Siemens VAI SIROLLCIS Sias (automatic surface inspection system) at the exit of the stand 4. Any defect is detected, recorded, classified in real time. According to the type of defect, the information is only recorded or transmitted to operator. Shall the defect be classified as coming from mill, like roll mark, information regarding the defect origin is given and operator is asked to take corrective action like changing of the faulty work roll.
Due to its compact layout, the carrousel reel solution is ideal for CM22. In addition it gives the advantage of identical coiling quality coil after coil, shorter strip length and smooth threading route during the coil change. Served by a high-speed rotary shear and three tail roll with magnetic table, cutting speed of the strip at 300 m/min is achieved. Advantages are naturally increased productivity and reduced off-gauge lengths due to highest speed while the weld seam is going through the mill. If required, the coil can be shifted to the visual inspection station just after discharging from the carrousel reel. The station is located next to the main pulpit in front of the carrousel reel.

Figure 18: Rotary Shear in Siemens VAI MT workshop in Montbrison, France

Electric and automation system

The drive solutions, the automation systems installed are very similar to those in the voestalpine mill. As the first coil was just rolled one week before submission of this paper the operational results will be presented shortly.

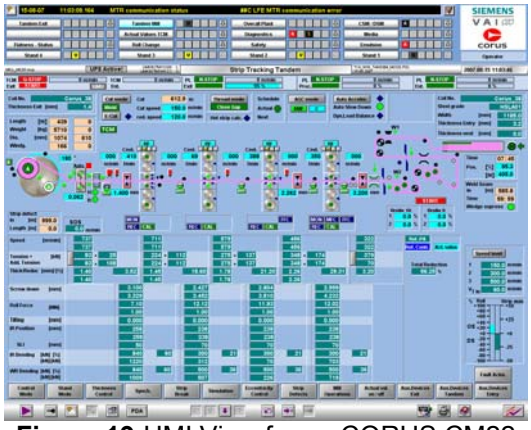

Figure 19:HMI View for on CORUS CM22

Conclusion

Siemens VAI supplied the two latest tandem cold mills in Europe; both are dedicated to high quality products and hard materials. Both the 4-high and 6-high design solutions and the automation systems were improved and adapted to fulfill the requirements for AHSS production. Due to pre-testing of mechanical equipment and the control systems already the very first strip produced on these mills were of sellable product quality.

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