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SIROLL CM—STANDARDIZED MODULES WITH FIT TO PURPOSE FLEXIBILITY FOR THE UPGRADING OF COLD ROLLING TANDEM MILLS TO CONTINUOUS OPERATION OR COUPLING TO A PICKLING LINE[1]

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Abstract
Today the installation of fully continuous rolling mills or mills coupled to pickling lines take clearly the precedence over the installation of coil to coil tandem cold mills. For a wide range of high-quality cold mill product applications continuous operation is the key to consistently reach the actual demands for quality related features due to strongly stabilized process conditions at high overall process efficiency. Continuous operating cold mills provide the capability for yield optimization and the basic environment to save operational cost. Making the operation continuous itself is often not sufficient to take full advantage of the inherent process potentials. Almost always supporting measures in the existing equipment and automation systems have to be implemented to take full advantage of the investment. SIROLL CM (Siemens cold rolling technology), the fully integrated Siemens cold mill system provides beside complete line solutions, thanks to its modular structure also a number of single solutions and mechatronic packages, which can be used very effectively for almost any upgrade needs. The consequent plug and play philosophy as well as the fit to purpose flexibility of its components makes it easy, cost effective and time saving to meet the upgrade objectives. This paper describes the numerous available upgrade packages from single machines to integrated packages inside SIROLL CM which can be used to target specific quality improvement, yield maximization as well as operation and maintenance simplifications measures at various positions inside a cold mill. The identification of useful upgrade measures is not always that obvious, even after long time of operation. SIROLL CM includes pure engineering packages starting with operation, function and quality studies at a mill to identify bottlenecks, shortfalls and improvement potentials. The paper will include suitable measures e.g. capacity studies, de-bottlenecking investigations or other process optimization steps.
Key words: Continuous tandem mills; Upgrade of tandem mills; Modernization of tandem mills.

SIROLL CM— MODULOS PADRONIZADOS COM O PROPÓSITO DE FORNECER FLEXIBILIDADE PARA MELHORIAS EM LAMINADORES A FRIO EM TANDEM PARA OPERAÇÃO CONTÍNUA OU ACOPLADOS A LINHA DE DECAPAGEM

Resumo
Hoje, a instalação de laminadores em tandem ou laminadores acoplados a linhas de decapagem sobressaem à instalação de laminadores a frio que processam bobina por bobina. Para um range mais amplo de produtos de alta qualidade laminados a frio, a operação continua é a chave para o alcance consistente da atual demanda por qualidade e eficiência. Operações contínuas de laminadores a frio fornecem a capacidade de otimização de produção e o ambiente básico para reduzir custo operacional. Fazer a operação continua muitas vezes não é suficiente para se ter todas as vantagens inerentes ao potencial do processo. Quase sempre, sistemas de medição e automação devem ser implementados para aproveitar ao máximo o investimento. SIROLL CM (Tecnologia Siemens para laminação a frio), o sistema de laminação a frio da Siemens completamente integrado, fornece além de completa solução para linhas, graças à estrutura modular, um grande número de soluções individuais e pacotes mecatrônicos que podem ser utilizados em qualquer melhoria necessária. A consequente filosofia *plug and play* propõe flexibilidade aos componentes, tornando mais fácil, barato e rápido o alcance dos objetivos. Este artigo descreve um número grande de pacotes tecnológicos desde equipamentos isolados até pacotes integrados dentro do SIroll CM que pode ser utilizado para melhoria na qualidade, maximização da produção e simplificação na manutenção e operação. A identificação da melhor opção de melhoria não é óbvia muitas vezes, mesmo após muito tempo de operação. Siroll CM inclui pacotes de engenharia começando por operação, funções e estudos de qualidade do laminador para identificar gargalos e melhorias de potencial.
Palavras-chave: Laminadores em tandem; Melhoria nos laminadores tandem.

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1 INTRODUCTION

Today the installation of fully continuous rolling mills or mills coupled to pickling lines take clearly the precedence over the installation of coil to coil tandem cold mills. For a wide range of high-quality cold mill product applications continuous operation is the key to consistently reach the actual demands for quality related features due to strongly stabilized process conditions at high overall process efficiency. Continuous operating cold mills provide the capability for yield optimization and the basic environment to save operational cost. Making the operation continuous itself is often not sufficient to take full advantage of the inherent process potentials. Almost always supporting measures in the existing equipment and automation systems have to be implemented to take full advantage of the investment.
SIROLL CM (Siemens Cold Rolling Mill Technology), the fully integrated Siemens cold mill system provides beside complete line solutions, thanks to its modular structure also a number of single solutions and mechatronic packages, which can be used very effectively for almost any upgrade needs. The consequent plug and play philosophy as well as the fit to purpose flexibility of its components makes it easy, cost effective and time saving to meet the upgrade objectives.
This paper describes the numerous available upgrade packages from single machines to integrated packages inside SIROLL CM which can be used to target specific quality improvement, yield maximization as well as operation and maintenance simplifications measures at various positions inside a cold mill.
The identification of useful upgrade measures is not always that obvious, even after long time of operation. SIROLL CM includes pure engineering packages starting with operation, function and quality studies at a mill to identify bottlenecks, shortfalls and improvement potentials. The paper will include suitable measures e.g. capacity studies, de-bottlenecking investigations or other process optimization steps.

2 METODOLOGY

2.1 System Structure

SIROLL CM is part of the SIMETALS portfolio of integrated complex products, starting upstream with iron and steel making (SIMELT), followed by Casting (SIROLL CA) and hot rolling (SIROLL HM). Downstream of cold rolling, SIROLL CM is in close connection to all kind of strip processing units like annealing, annealing-metal coating and organic coating, captured under the SIMETAL component SIROLL PL, which at its very downstream end also includes all facilities to tailor the final product to the needs of the end customers, like cut-to-length, slitting and other finishing facilities.

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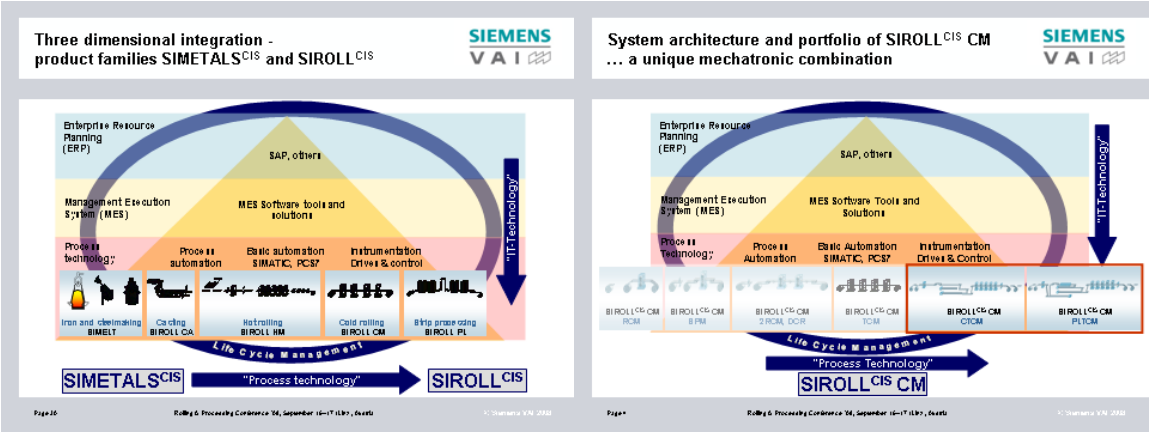

Figure 1. SIROLL CM inside the SIMETALS solution (left), the SIROLL CM portfolio (right).

SIROLL CM comprises all production units for the transformation from hot strip into pickled & cold rolled strip. The continuous representatives of such facilities are the continuous tandem cold mill (CTCM) and the linked pickle line – tandem cold mill (PLTCM).

SIROLL CM internally, like all other SIMETAL components, has a well defined structure from machine level to line (production unit) level and the integration of such production units into production complexes, like complete cold rolling facilities.

Substantial care was taken in the past years to optimize the vertical and horizontal integration of all units into an integrated system of mechanic and electric & automation based on the use of highly standardized components and a suitable substructure to make such components reusable in various related applications. These substructures or modules typically are mechatronic packages, meaning that machines, sensors, controls and models (where applicable) form a functional unit to fulfill certain tasks. The pluralities of functional units are aggregated into the overall system by plug & play interfaces. The interfaces of modules to the existing environment are flexible in nature to fit into many applications, i.e. also upgrades or modernizations. Key element in any case is that the internal structure of modules is not changed, although it is possible to enable / disable components as required by an application.

Due to this architecture the adaptation engineering is kept low, project implementation fast and at minimum risk. Life-cycle and derived services are mandatory elements and safeguard the full availability of all components over a long time span, their continuous further development and quick support of all kinds in cases needed. The application of this idea for upgrades into continuous cold rolling operations is briefly introduced in the following chapters.

2.2 Upgrade Solutions

Typical starting scenarios for upgrades of tandem cold mills into continuous operations are:

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2.2.1 Existing batch type tandem cold mill extended to a continuous tandem cold mill (CTCM)

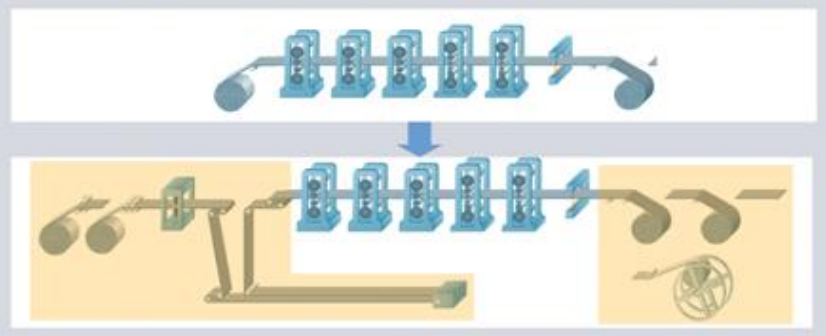

Figure 2. Tandem Cold Mill (TCM) upgrade to a Continuous Tandem Cold Mill (CTCM).

The upgrade to a CTCM even without a power increase in the mill includes a large potential for capacity increase due to the cancellation of threading and unthreading operations. Improvement of quality, yield and operational savings compared to batch operations are natural gains. Still unfavorable certainly is the non existent link the pickling line, which requires in between coil handling and coil storage provisions, which themselves can have adverse influence on quality yield and the cost saving potential of just-in-time processing from hot coil to pickled and cold-rolled coil. However in practice scenarios can exist but are not limited to where:

- There is no continuous pickling line or none such in manageable range to the tandem cold mill to establish a full coupling
- The capacity of a nearby pickling line and the mill are far different (typically if such a PL produces large quantities of pickled & oiled, say as pickled & oiled sold hot band in a gauge range up to 6 mm).
- The pickling line is of push-pull type PPPL. Such PPPL can be one of the substrate origins for the CTCM for the following reasons:
  - The PPPL (of large capacity, i.e. > 800,000 t/a) can operate strip beyond 6 (7) mm of hot band, in which all products beyond 6 mm will be sold as special purpose pickled & oiled hot band (classically such products are pickled in plate pickling lines in annual quantities of markedly less than 500,000 t/a and typically includes upper hardness range HSLA, tool steel and today also multiphase steel)
  - The existing pickling capacity in a plant is split into various lines for reasons like the separation of high Si grades from the rest, or simply by formerly materialized plant extensions.
- Bundling of HSS and AHSS products into one mill (preferably a CTCM) with various (plant) internal and external hot band sources.

In all such cases a TCM to CTCM upgrade can make sense if capacity and yield increase along with a cut of operations cost in the cold rolling step is of essence and / or the existing cold rolling equipment cannot cope with product mix extension regarding size and today mostly existent regarding HSS and AHSS capabilities. In practice individual cases have to be analyzed carefully. From Siemens VAI experience, unless case I or III b from above is present, there often is a rather fuzzy borderline between quality and capacity gain and their financial impact versus total production cost cut to guide a decision for a TCM to CTCM upgrade. Predominantly the existing product diversification, i.e. share of pickled & oiled to pickled & cold

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rolled and in addition the gauge range of pickled & oiled products along with the business model of the producer drives the final route to be taken.
Important to mention here is that a TCM to CTCM upgrade can be considered as an intermediate step from a separate pickling and cold rolling operation into a fully linked one. A CTCM can be built with the potential to add at affordable cost the pickling step later.

2.2.2 Coupling of an existing continuous pickling line with an existing tandem cold mill

The direct coupling of an existing pickling line with a tandem cold mill is certainly the best method for an upgrade into continuous operation.

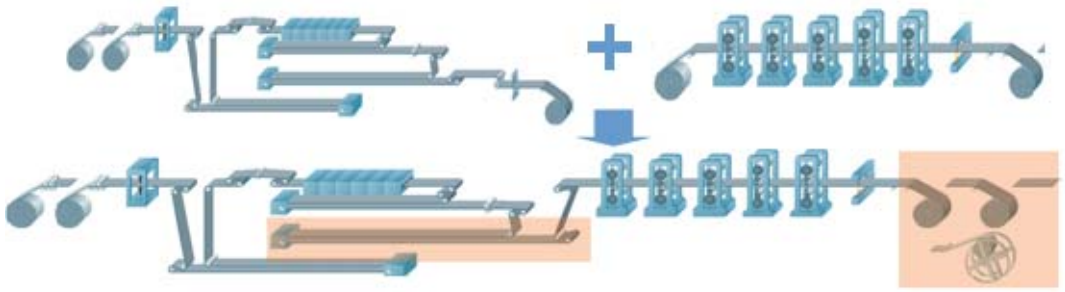

Figure 3. Pickling line + Tandem Cold Mill upgrade to PLTCM.

Basically such links can mechanically be established by adding a link accumulator between the PL exit and the TCM entry and replacement of the old TCM entry by bridle and steering units, shear and strip clamps and installation of a second tension reel on exit of the TCM. This of course assumes that all other equipment in the PL as well as the TCM can be reused for the continuous operation. Simple cases like this are rather seldom in practice. In most cases beside the link itself a variable number of other equipment has to be upgraded (changed) as well. Without additional measures the linked operation provides already some capacity increase relative to the single operation of the PL and TCM.
If the capacity target is beyond this limit, the process speeds in the PL and / or the TCM have to be increased which triggers a series of consequential changes starting with the increase of drive powers in the PL and TCM, quite often also a change of the complete TCM speed cone (drive powers + gear ratios) and the extension of the PL process section. A change in process speeds can also affect the size of accumulators, which then requires also a modification of the existing accumulators of the PL.

3 RESULTS AND DISCUSSIONS

3.1 Standardized Modules with Fit to Flexibility Purpose

The extent of modifications / adders to upgrade into a CTCM or a PLTCM strongly varies from case to case dependent on the main objectives for the upgrade and the installed base prior to the upgrade. Taking this into account, a selective step-wise and flexible approach is required in practice to meet individual targets without compromising the benefits of a solid and proven design base and its interaction with associated sensors, controls and models in a strict all-embracing mechatronic system. A straight forward solution in such cases is to utilize a modularized system, which exhibits certain flexibility for tailoring to existing ambience, without the need to

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change internal structures of any kind. The inherent advantage is that such modules are highly standardized and designed to perfectly support a plug and play philosophy in particular at the interfaces to the associated electric & automation systems. All these modules from sensor (actuator) level up to the process control and process model level are well tuned and allow selective use of their in-built functionalities tailored to individual applications. Obvious advantages there from are:

- modules require only adaptation engineering
- reduced engineering lead time shortens project execution time
- the standardized machines inside these modules are well proven and life-cycle optimized (preventive maintenance indicators, extended wearing ranges, smart tools for wearing part exchange, lower number of spare parts etc.)
- system integration and testing is fast by avoiding time intensive troubleshooting
- commissioning period can be shortened without compromising a safe achievement of the performance objectives

The following modules for upgrade into continuous operation of either type are available:

Table 1. Modules for upgrade into continuous operation

Module Name	Basic Content		
Upstream TCM	All equipment of CTCM or PLTCM upstream to the TCM	CTCM	PLTCM
Line entry	Provides all equipment for a fully continuous entry section (excl. the welder)	✓	✓
Welder	Heavy laser type or flash-butt type	✓	✓
Accumulator	2, 4 and 6-strand accumulators to link different sections, …	✓	✓
Scale-breaker	Scale breaker in various sizes and design solutions		✓
Pickling process	Pickling process section including acid-concentration control, pH-control and setup		✓
Side trimmer	Side trimmer, scrap chopper + scrap handling, notcher, asso. steering systems		✓
P&O Take off	Shear, pinch-roll unit and tension reel for P&O		✓
Safety 1	All safety systems up to the mill area	✓	✓
Tandem Cold Mill			
Continuous entry	Steering and bridle units, shear		
AGC	AGC capsules		
Flatness	Roll shifting / SIROLL SmartCrown®, roll bending		
Roll change	Automatic work-roll change, backup-roll change, pass-line adjustment,		
Drive	Gears, spindles, couplings, save-sets for main drives		
Cooling & lubrication	Cooling headers for rolls and strip, direct application equipment, wipers, emulsion and DA systems, strip blow-off systems		
Continuous exit	Flying shear, tension reels, strip inspections		
Mill stand	Rolls, chocks, BUR bearings		
Safety 2	All safety systems in the mill area		
Condition monitoring	Vibration monitoring, vibration control		

3.2 Examples for Selected Modules

This chapter should provide a brief overview about the content and features of selected modules for the upgrade of tandem cold mills to continuous operation. The modules are selected to outline the basic methodology for such projects and concentrate in first place on those modules mandatory dependent on the type of

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upgrade as outlined under chapter 3, followed by a few which are optional. Which modules or part of modules have to be utilized finally depends on the specific upgrade objectives. As per Siemens VAI experience this is a wide field of applications ranging from complete conversion from batch type operation into continuous or is only a single machine or unit in cases of modernization / extension of already continuously operating lines.
Detailed information on modules not described in the following can be found in various Siemens VAI brochures and technical papers dealing with this subject.

3.2.1 Line entry and welder

The entry section of continuous lines is crucial for the overall performance of the line. Dependent on the bottleneck situation for a given product mix a considerable portion of bottlenecks can be located here. This always happens if the specific coil weight on average is small - a quite frequent case in upgrades - which makes the operational cycle time and low disturbance rate of this section to key performance indicators. The line entry module basically offers two distinct types, the classical 2 Reel and the so called 1½ reel solution.

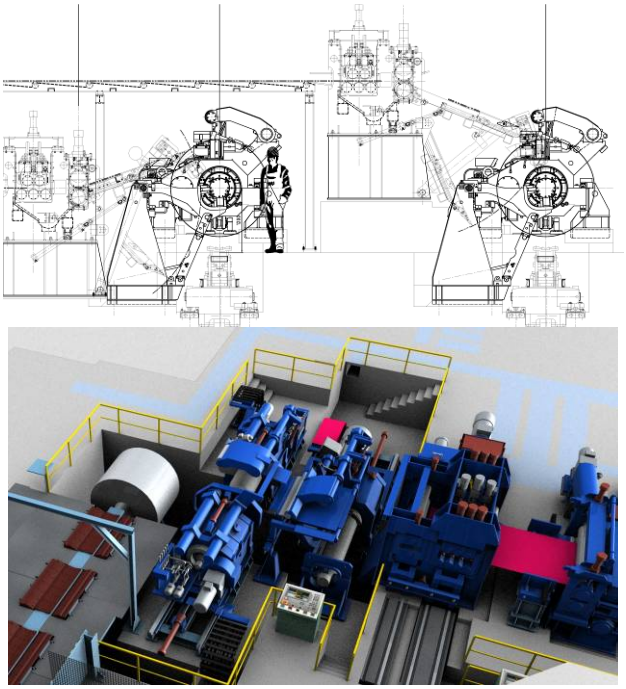

Figure 4. 2-reel entry (left), 1½ reel entry (right).

The two-reel type consists of two on top of each other located pass lines, each line fed by a pay-off reel, which join into a single-pass line just before the welder. Evidently each pass line needs the reel, pinch roll unit, flattener, start-stop shear and scrap removal. Definitive advantage of such arrangement is redundancy which allows operating the entry at increased cycle time even if one pass line is out of service.
Much more compact is the 1½ reel type, where only one pass line exists. The coil loading into the pay-off position is done by a helper reel (typically stub type) with a two-step sequence, i.e. first step while the actual coil in the line is on the pay-off and second step when the tail-end of this coil is sheared and positioned at the welder. Beside its compactness the beauty is that only one flattener and scrap removal is needed which is also valid for the shear, although the shear in this case for

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performance reasons should be of flying type. The Siemens VAI standard solution is a fast, robust and smart monitored pendulum shear.
The standard built scrap removal work with one scrap box located underneath the shear (which also takes the shearing scrap from the welder via a conveyor belt). A trolley system allows a quick emptying at low noise of the scrap box(es) via tunnel and provides an free designable interface to the further scrap handling facilities.
Any entry type can be combined with a variable size walking beam or coil car system, an automatic coil prep and de-banding station. For a maximum on operational stability a strip head end conditioning is foreseen to avoid threading jams, which provides low susceptibility against incoming hot-coil quality (shape and hardness) variations.
The standard welder type offered today as another integrated module is the heavy gauge laser welder with integrated shears and notching unit, powered by a 8 KW CO_2 laser source. Hardening susceptible grades can be post-annealed by an optional available integrated post-annealing device. As an alternative a flash-butt laser welder with same functionality is available as well. Entry module(s) and welder(s) are optimized in terms of mechanical and electric/automation interfaces which provide a real plug & play system.
Thanks to the high degree on automation included in any of the entry modules the operation can be controlled basically by one operator in the entry pulpit. Mostly convenient is certainly the 1½ reel type since it provides an almost 270 deg direct vision field from the coil loading up to the welder.

3.2.2 Accumulator module

The accumulator module provides all tools and tackles to join any line section with another one. Various types of horizontal accumulators (2-, 4- and 6-strand) are available with constraint or free looper car pulling systems via ropes and winches.
The automatic door opening / closing system is a mechanical link motion system with smart locking at the end positions to maintain utmost dynamic stability even at high car speed.

Figure 5. Typical accumulator (4-strand in this case, left picture), helical 90 deg turn device (right).

Looper car motion can be wireless monitored to detect acceleration / deceleration abnormalities which allows quick strip break detection and provides utmost safety against possible damages.

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Strip threading ropes and winches and a door maintenance trolley (insert able on the looper car rails) are included in the standard tools. Optionally also strip lifting devices can be offered to quickly recover from strip breaks inside the accumulator.
Always parts of the accumulator module are the associated strip steering and bridle roll units to form a complete integrated and controllable system in a mechatronic sense. Beside this also any needed strip diversion device like helical turns (standard) or turning towers are available in this module. Helical turns have minimum space requirements and can be used simultaneously at multiple positions, which provides a powerful tool to fit accumulator packages even into very complex layouts.
The accumulator module in any possible configuration is designed for zero disturbance rate and minimum maintenance effort (typically once per year).

3.2.3 Pickling process section

The pickling process section module includes the complete chemical treatment section (pickling tanks, rinse) up to the strip dryer with all associated acid, rinse water (steam condensate) and off-gas circulation systems and drain / draw off interfaces. The standard is based in hydrochloric acid and full polypropylene tank and pipe systems. The tanks are standardized at 20, 26 and 32 m of length and of shallow, centenary type. The acid jet system provides a high turbulence flow around the strip inside the tank; the turbulence intensity can be controlled by variable speed circulation pumps. For high-speed pickling each tank is equipped with a jet pump actuated exit to entry (horizontal) acid re-circulation system which ensures a minimum of acid drag out into the wringer roll boxes. Thanks to a perfect gas tight water seal between tank and its lids, acid fumes are taken off only inside the wringer roll boxes and cleaned in a 1- or 2-stage scrubber to provide a minimum of discharge into the ambiance.

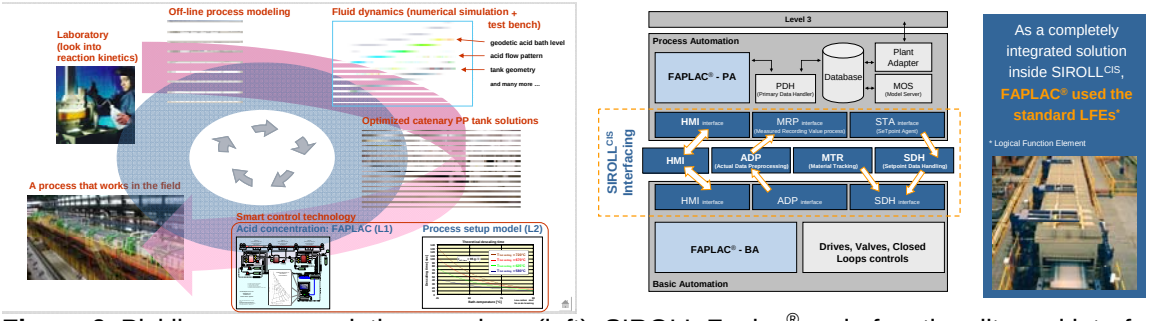

Figure 6. Pickling process solution envelope (left), SIROLL Faplac® main functionality and interfaces (right)

Acid flow from circuit to circuit is in n-stages counter cascade and allows free as well as forced cascading. The rinse section, typically of 5-stage counter cascade type ensures lowest chloride residuals on the strip surface after the process section.
A unique feature of this module is its integrated acid concentration control, various pH controls inside the rinse and the pickling process model, concentrated in the SIROLL Faplac® system with plug & play functionality into the overall control and model architecture of SIROLL CM. Highly advanced sensor and modeling technique provides the basis for very accurate acid concentration measurement in all tanks which in turn is the basis for product requirement dependent stable but quickly adjustable conditions and a very low overall acid consumption.
It goes without saying that the pickling section module offers easy configurable standard interfaces to tank farms and acid regeneration plants. The module is case

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sensitive tuned for optimized overall mass balances to reach minimum acid consumptions and to meet the continuously lowered emission standards.

3.2.4 Tandem cold mill – continuous entry and exit modules

The tandem cold mill related modules for the upgrade to continuous operation in first place are those providing the operational continuity of the cold rolling process. The continuous entry module provides the basic interface of the mill to a CTCM or PLTCM upstream configuration. It consists in essence of the entry steering system(s), the immediate to mill bridle unit, a start-stop shear and strip clamp and optionally a scrap removal system. Medium tension level strip steering (the steering unit is before the last bridle roll set) has the advantage of being less edge crack promoting, in case of susceptible grades. The steering effect is damped by the bridle unit which is beneficial for the edge built-up quality of the coil at re-coiling. The (typical 2 roll) bridle unit is part of this module, because for the advanced mass flow control (as part of the gauge control) it acts as stand #0. Optionally the module offers a convenient scrap removal system underneath the shear by a scrap box and trolley car. The exit module basically includes a high-speed flying shear (standard is a drum shear) with associated pinch-roll unit and offers two choices for the tension reels:

- Carrousel tension reel
- Two sequential tension reels (incl. magnetic carry over tables and strip switches)

Figure 7. Tension reel solutions of the continuous exit module (two-tension reel (left, carrousel (right))

Advantage of the carrousel tension reel is the compact design, only one belt wrapper and coil car as well as no magnetic carry over tables and strip switches. There is only one pick-up position at which the strip supported by a close upstream located pinch roll is thread onto the mandrel, which safeguards a precise threading and coiling even at very high threading speed. Since the threading / coiling geometry for each strip is identical, coil edge built-up quality for each strip is ensured and commissioning optimization is faster. A certain disadvantage of carrousel reels is its incompatibility with in-line strip inspections (sample cut and transport to the inspection out of the running strip). This is the reason why high-quality producers (automotive, etc.) often prefer the two-reel solution in conjunction with an in-line inspection. Part of the exit module are various choices for coil cars and other strip conveying systems including coil banding, marking / labeling and optionally a coil-eye welding unit. This is tailored to the specific need. Strip inspection is also part of the continuous exit module and offers two choices as follows:

- Inline strip inspection station downstream the exit
- Automatic (fully online) strip surface inspection system (SIAS)

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Figure 8. Inline strip inspection systems in the continuous exit module (automatic type in the right picture)

3.2.5 Tandem cold mill – roll change module

To take full advantage of a continuous mill also the mills roll change should be upgraded accordingly. Basic content of this module are a) quick automatic work roll change systems for 4-high and 6-high types, b) Backup roll change system and c) the automatic pass-line adjustment.

Figure 9. Automatic work-roll and backup-roll change system.

Work-roll change which such systems can be performed in just a few minutes and requires a minimum on manual intervention dependent on the work roll bearing lubrication system (disconnection and connection of lube hoses, optionally available also with automatic systems).
Standard for an automatic pass-line adjustment is a hydraulic cylinder actuated, single wedge per side system located on the bottom of each mill stand.
During work-roll change the strip should remain in the mill which in most cases also requires some mechanical modification inside the mill as rails and wheels for the work-roll chocks to be added. On very old mills it may also require a modification of the backup-roll chocks (systems where the WR chock is guided by the BUR chock) and consequently also modified, but mostly new bending blocks.

3.2.6 Tandem cold mill – drive module

If an upgrade to continuous operation is also associated with an increase of mill speed and / or extension of the product mix into HSS and AHSS products, the main drive system (mechanical and electrical) need to be taken into consideration as well. The roll torque and speed requirements after the upgrade have to be analyzed systematically and a new speed cone developed which finally drives the extent of

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modifications necessary. In the simplest case gear ratios have to be modified which is typically done by a swap (relocation) and partial replacement of gear boxes. This mostly goes along with a swap of existing main drives and their partial replacement by new ones for certain mill stands. If speed and roll torque increase are getting significant the entire mechanical end electrical drive system has to be replaced which beside the gear boxes includes the drive spindles, spindle holders, couplings (and save-set couplings) and the drive (and its electrical backup system) itself.
The drive module offers a verity of solutions, mechanical as well as electrical to fit into any possible requirements. In case of full replacement of entire drive trains for some or all mill stands the option between pinion and twin-drive solution exist. Tandem main drives can be modified into a single main drive per stand or two-pinion or twin (one per work roll) connected drive systems and many more.
Drive modifications always include a detailed analysis and optimization with regard to drive dynamics. Torsional stiffness is optimized to meet crucial natural- and absorption- base frequencies requirements. Even parametric excitation is taken into consideration to get an optimum, mechanically stable, dynamic drive system over the entire operation range of the mill. Highly important is also the type of main drive. Standard in the drive module are synchronous AC drives because of their outstanding response behavior. Other solutions like asynchronous (induction type) AC and DC are of course available as well, but a second choice since utmost gauge performance has a lot in common with drive response capabilities.
A final remark shall be that the drive module also includes as an option smart condition monitoring systems to continuously provide a health check of the equipment. Such systems deliver valuable information about the actual wearing conditions in spindles, couplings and gears and by this provide the basic indicators for an efficient proactive maintenance scheme and in turn a low to zero disturbance rates for all equipment involved.

3.2.7 Tandem cold mill – AGC and flatness module

Both modules are not a standard pre-requisite for upgrades into continuous operation if the existing systems can fulfill the required performances for the continuous operation. This is verified as part of the analytic scope of this module by default.
The AGC module covers the whole range from the hydraulic in-house manufactured capsule, its embedded position measurement system, the hydraulic supply chain (servo valves, servo block, HP supply station and connecting piping systems in-between all components) and the control system on top of it. The standard type of capsule is double acting, with an integrated position sensor and direct mounted servo block with excellent response behavior and minimum maintenance requirements. On top mounted position sensors and single side active controlled solutions are available as well.

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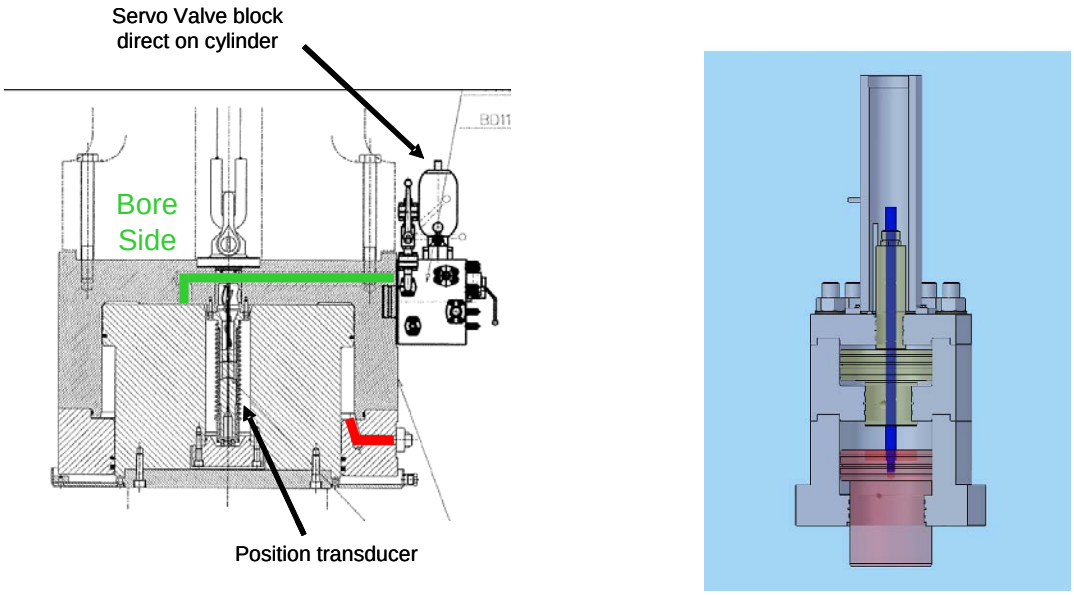

Figure 10. AGC capsules (left the standard type, right the booster type).

A special type, developed for retrofit cases is the booster AGC, which fits into typical spaces of existing spindle and nut gauge adjustment system. The flatness module consists of all mechanical and sensor equipments to control the strip flatness in 4-high or 6-high mills. These equipments are closely connected to the control and setup model part of SIROLL CM by a plug & play interface, which allows utilizing the various equipments and sensors in an optimum way at low engineering and commissioning efforts.

Technological backbone is the work- and / or intermediate roll shifting system and the universal SmartCrown® roll contour, in conjunction with all kinds of work- and intermediate-roll bending systems and the multi-zone cooling. A verity of flatness sensors is available for the on-line measurement. The contactless working SIROLL Siflat system is the standard, supplemented by two types of shapemeter rolls to optimally cover all in practice possible cases for accurate flatness measurement. The last stand of tandem cold mills by default is equipped with a closed loop flatness control system. For advanced solutions, i.e. on mills rolling AHSS grades, multiple flatness measurements located upstream to the last stand can be used for pilot control of bending setups to cope with strongly varying operation conditions (incoming material, speed, thermal fluctuations, etc.).

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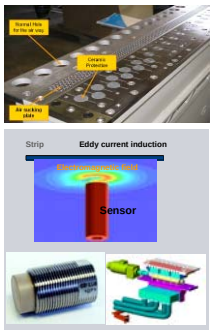
Requirements	SmartCrown® Features
Large control range	▪ Significantly enhanced control range compared to work / intermediate roll bending
Minimum number of roll grinds per mill stand	▪ Replacement of all conventional grinds with a single SmartCrown® roll
Flexible pass schedule design	▪ More flexible pass schedule design due to single roll contour
Easy-to-implement control characteristics	▪ Almost linear relationship between work roll shift and equivalent roll crown
Simple and robust mechanical design	▪ Lateral shifting performed by means of standard hydraulic cylinders
Capability to suppress all types of buckles	▪ Enhanced shape control by suppression of quarter buckles



Functional principle

- Distance range between the strip and Siflat: 1.0 mm to 6.0 mm (Maximum 6.6mm)
- Frequency excitation from 6.0 Hz to 10.0 Hz
- Excitation amplitude approximately 100µm
- Maximum exit thickness = 5.0 mm
- Application area: after last mill stand

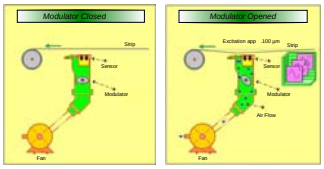


Figure 11. SmartCrown® features (left), Siflat functional principle (right).

The flatness control system features self-learning parameter optimization for adaptation to the rolling conditions and material properties. This includes variable (selective) gain controllers for commensurate, case dependent control reaction, dynamic bending adjustment range optimization by spill over functionality in conjunction with the roll shifting system(s) and disturbance variable feed forward for dynamic set-up tracking to accommodate changes of crown and wedge on the incoming strip as well as in the thermal buff of the rolls. For the bending setup a sophisticated roll stack deflection model is available as part of this module as an option.

3.2.8 Plant safety modules

Plant safety in SIROLL CM is available in two modules, one concentrated on the continuous entry or pickling line and all linking facilities and the other for the mill area itself. Today safety is an add-on must in upgrade to or modernization of continuous lines. It is a topic at least in parts even on replacement of single units. Due to statutory character of plant safety, the modules developed for SIROLL CM have been designed very carefully with the objective to provide as much as possible flexibility for their practical application without compromising operation and maintenance convenience.

Requirements in particular in Europe regarding plant safety have been tightened during the past years in order to minimize the risk of accidents during operation or maintenance. Special emphasis is taken on safety engineering during the planning and design phase. A systematic risk analysis is carried out to eliminate potential hazards, to define counter-measures and any remaining risks. Computer-assisted training of operators and maintenance personnel is another key element being addressed. The plant safety package included in SIROLL CM fully complies with European machine directive MSR 2006/42/EG and subordinated standards. As such it fulfils also most of other safety standards outside Europe by default. As it is modular in the design, it can, if local regulations allow, be simplified and tailor-made to the customers needs.

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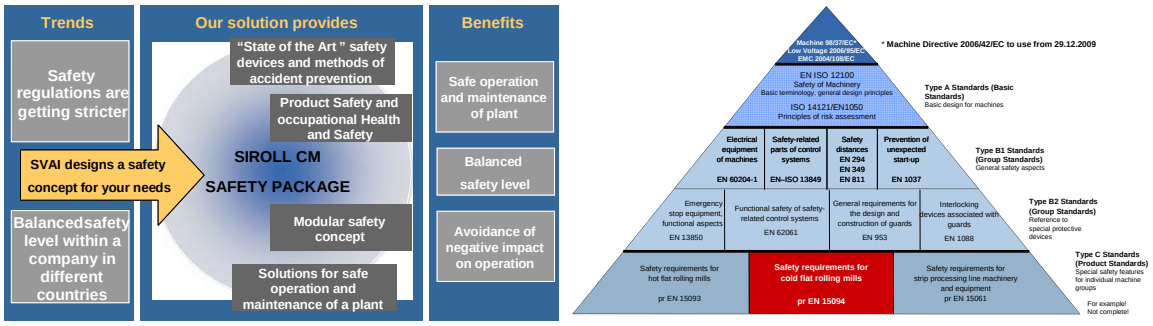

Figure 1: Safety overview (left), safety directive and standards in Europe (hierarchically, right).

Beside the mechanical and fluid components associated with safety, an important part of the system is the control by a safety PLC. This logic controls all safety areas of the plant and takes respective actions in case access is requested through the safety gates. The actions taken by the system depend on the current operational conditions in respective safety areas with the objective to always ensure maximum safety of people entering in such areas. The status of the system at any time can be seen on the HMI to keep the pulpit operators aware of anything going on in the plant areas.

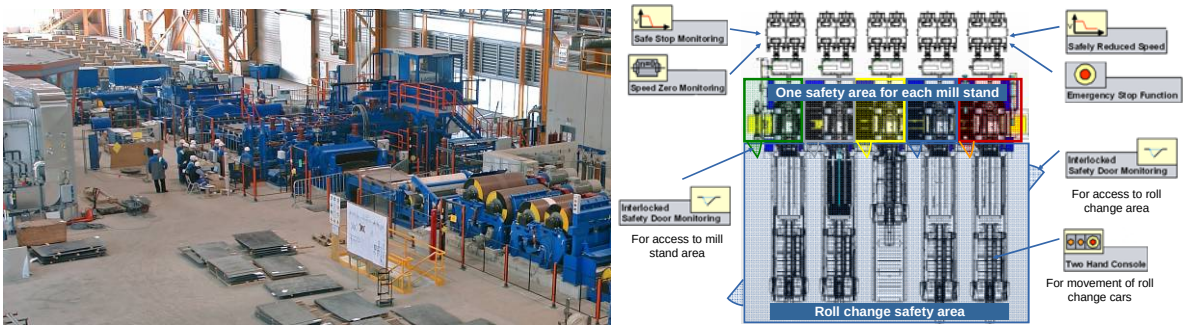

Figure 2. Entry safety systems during erection (left), safety layout for the mill stand area (right).

4 CONCLUSION

As a concluding chapter to this article some information should be provided about the Siemens VAI methodology to assist and support customers already in the planning phase for such projects. Typical for this kind of projects are combinations of targets like:

I. Increase of production capacity,
II. Extension of product mix into HSS and AHSS grades
III. Improvement of quality yield and product quality in general
IV. Shortening of total production time (just in time production)
V. Reduction of cost for operation and maintenance spares
VI. Reduction of manpower for the operation and maintenance
VII. Reduction of emissions and energy savings

Items III to VI above to some extent are inherent gains compared to the batch operation when making a line continuous. The potential for per tonne energy saving is limited and can be found predominantly in possible flow reductions of large quantity volume circuits in the pickling line but also for instance the emulsion system(s) of the tandem cold mill. The pickling process and the cooling & lubrication module offer some levers to take advantage of that.

The basis and starting point of the planning is certainly the anticipated future product mix in terms of dimensions, steel grades and annual quantities for the future

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production. On this basis it has to be investigated by various types of simulations and special calculations, which upgrade measures, need to be taken into consideration to accommodate this mix. This procedure can become quite sophisticated in particular if there are many side conditions (constraints) like space requirements, relative location of installed base, conditions of existing foundations and buildings, etc. need to be taken into consideration. Sometimes it can turn out that under given conditions a particular mix can't be accommodated, which then requires further investigation steps to find remedies, i.e. some product mix optimizations, etc. Beside layout consideration also the existing equipment(s) have to be analyzed quite in detail to obtain a clear picture on their capability for reuse in a new environment with different operational conditions. This finally should yield a rather clear overview which modules as described above have to be selected to meet the project objectives best.
To keep capital cost as low as possible the reuse of existing equipment(s) always is a key element for the customer to be observed and whenever possible satisfied. However this request has to be seen in a balanced context to the experience that by this the complexity of interfaces to be satisfied can grow exponentially (mechanically but even more pronounced in E&A), which in turn can lead to a substantial degradation of benefits the use of standardized modules with a certain (but always limited) flexibility provides.
To still keep cost limited, a remedy can be to look into a categorized approach concerning real required and nice to have items without jeopardizing the main objectives and / or seeking feasible alternatives to stretch a total capital investment over more than one investment period by a step-wise upgrade scheme.
The solution finding process in each individual case is a recurring one until it converges to a compromised balance. Typically considerable engineering effort has to be spent in this phase to find out what is best at still affordable cost. To keep this process short and efficient, Siemens VAI has developed a large number of special tools to support the fact and solution finding in an optimum way. The use of 3D design and layout provide another powerful tool to tailor the above introduced upgrade modules to any specific requirements without compromising their plug & play functionality.
If only very vague ideas are existing on how to develop from an existing installed base into continuous production, Siemens VAI offers dedicated studies to support already in a very early stage with fact finding, simulation and principle layout considerations (including also any associated logistical topics) to finally develop attractive upgrade scenarios with a clear indication about associated cost and added value potential.
Thanks to the design of our upgrade modules with a unique embedded sensor, control and model structure as well as easy to adapt interfaces to the ambiance, the upgrade to continuous operation from any installed base can be precisely planned, offers shortest realization schedules and is safe to achieve the project objectives.