LATEST SOLUTIONS FOR HIGH OUTPUT COUPLED OR CONTINUOUS COLD ROLLING MILLS[1]

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Abstract
Under the pressure of the market steel producers have to rationalize their equipment and operation to reduce the USD/ton cost, to fulfill the high quality and productivity demands and to reach high profit. With high productivity and low operating cost the coupled or continuous lines are now the standard for new or modernized tandem cold mills. Siemens VAI supplies integrated solutions from equipment to automation to help cold strip producers improve their production efficiency and quality. This paper describes benefits that have been achieved by our customers using our SIROLL^{CIS} CM solution for high productivity cold rolling mills, including: Specific technological solutions such as welders, flatteners, shears, tension reels, engineering tools used to find optimized layout solutions and operation practices; Process Control Packages using fast control techniques, physical models, operator interfaces and sequence control. Highlights of the latest projects will be discussed, including the new tandem cold mills for voestalpine Stahl Linz, CORUS IJmuiden and Tangshan, as well as the revamp orders in Arcelor Mardyck, Essar Steel and Liuzhou which aimed on increasing the production output and improve thickness, flatness and surface aspects of the produced cold rolled strip.
Key words: Cold rolling mill; Increased production output.

ÚLTIMAS SOLUÇÕES PARA LAMINADORES DE TIRA A FRIO DE ALTA PRODUTIVIDADE ACOPLADOS OU CONTÍNUOS

Resumo
Sob a pressão do mercado os produtores de aço têm que racionalizar seus equipamentos e operação para reduzir o custo de USD/ton, para cumprir as demandas de alta qualidade e produtividade e alcançar o lucro elevado. Com produtividade elevada e baixo custo de operação as linhas acopladas ou contínuas são agora o padrão para novos ou modernos trens de laminadores a frio. A Siemens VAI fornece soluções integradas desde o equipamento a automação para ajudar os produtores de tiras a frio a melhorar sua eficiência e qualidade da produção. Este paper descreve os benefícios que foram conseguidos por nossos clientes que usam nosso SIROLL^{CIS} CM: solução para elevada produtividade em laminadores a frio, incluindo: específicas soluções de tecnologia como máquinas de solda, desempenadeiras, tesouras, enroladeiras, projetando as ferramentas usadas encontrar otimizadas soluções da disposição e práticas de operação; Pacote de Controle de Processo que utiliza rápidas técnicas de controle, modelos físicos, interface com o operador e controle de seqüência. Os destaques dos últimos projetos serão discutidos, incluindo o novo trem de laminador a frio pela Voestalpine Stahl Linz, CORUS IJmuiden e Tangshan, assim como o novo pedido de atualização na Arcelor Mardyck, Essar Steel e em Liuzhou que apontaram um aumento na produção e melhoram aspectos da espessura, do nivelamento e da superfície da tira a frio produzida.
Palavras-chave: Laminador de tiras a frio; Aumento de produção.

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INTRODUCTION

The continually increasing demands placed on product quality and low-cost production are forcing producers of hot-rolled strip to permanently look for equipment improvements and more efficient rolling operations. Considering the major investment expenditures necessary for new hot-strip mills, it is far more feasible to investigate the "hidden" potentials of existing facilities. Modernizations and improvements should not significantly affect ongoing production operations, must be rapidly implemented and, above all, should assure a short return on investment. For a plant modernization to be successful, in-depth knowledge about the strong and weak points of the mill and processes is necessary, and the close cooperation with an experienced engineering and plant-building partner is vitally important.
Out of the above 220 existing cold rolling tandem mills in operation worldwide, more than 40% are either coupled to a pickling line, or are fully continuous cold mills. This ratio keeps growing, as it is now a proven fact that continuous process is the best configuration for tandem mills to optimize productivity, yield and quality.
By converting more than half of the existing mills, Siemens VAI has been able to experience and tune many different solutions and measure their specific advantages and drawbacks in regard to each mill specificity and mix.

FROM BATCH TO CONTINUOUS MODE

Production capacities of tandem cold mills using coil-to-coil operation are typically in the range of 600,000 to 800,000 tons per year.
Today many of the existing batch mills are extended and modernized to continuous mode and new mills are installed for continuous operation from the very beginning. Depending on the product mix, production capacity of these continuous mills can reach 1.2 million tons per year or even more, and many quality parameters can be improved.

GENERAL REMARKS ON TARGETS OF MODERNIZATION OF CONTINUOUS COLD ROLLING TANDEM MILLS

Today most of the modernization projects in cold rolling mills follow two general target groups:

Target group 1: decrease of conversion costs

Cost elements for a decrease of conversion costs are:

- Costs for energy (deformation energy, energy for other mill equipment like pump stations etc.),
- Costs for maintenance and consumables (maintenance personnel, rolls, general wear parts, spares, emulsion, etc.)
- Costs for operation personnel
- Capital cost for the material which is under production or on stock

Depending on specific cost structures and interna interfaces, some producers also consider the costs for transport of coils as conversion costs. Figure 2 shows the benefits which can be reached in a modern tandem mill compared to the batch process, which is represented by the 100 % line.

Characteristic numbers for benchmarking

Productivity, availability and yield are all definitions which describe the production capability of a mill. These numbers are often used for benchmarking. This benchmarking has to be done very carefully, i.e., the current product mix, the layout,

the market, the equipment, etc. have to be considered. The productivity will hardly be comparable, if one mill has a share of very thin gauges of 5 % and the other mill has a share of 20 %. Today's availability of conventional cold rolling mills (actual net rolling time related to planned net rolling time incl. scheduled roll changes) between 70 to 84 %, the yield (weight of coiled strips related to weight of charged slabs) is typically 98 %.

Target group 2: adaptation of the cold rolled strip products to the market requirements

These targets are dealing with the product itself and can be divided into three areas:

- Improvement of product quality (thickness, surface, flatness, etc.)
- Extension of the dimensional range of the product mix (wider, thinner, etc.)
- Extension of the steel grades mix (e.g. DP-steel, TRIP-steel)

The following sections briefly present measures to reach improvements either in terms of decrease of conversion costs or adaptation of the cold rolled strip products to the market requirements and illustrate them with recent references:

- Strip feeding and welding section
- New development for line entry layout
- Accumulators and strip turning equipment
- Tandem mill entry design and benefits
- Tandem mill design features
- Flying gauge change and speed optimization
- Tandem mill instrumentation
- Coiling sections with two reels or carrousel configuration
- Overall equipment efficiency

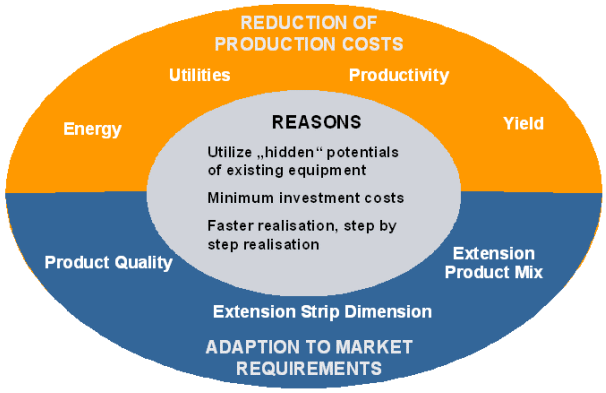

Figure 1: Reasons and targets of modernization projects

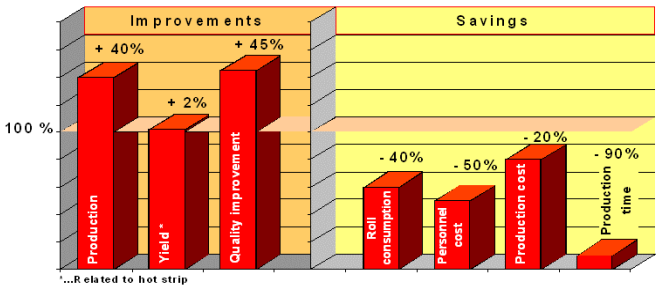

Figure 2: Typical cost distribution of a continuous cold rolling tandem mill

STRIP FEEDING AND WELDING SECTION

This section has a very high impact on the line performance and must be designed to ensure high feeding pacing and rollable welds, whatever the product grade and size, according to production scheduling constraints.

The feeding section must, therefore, be fully automatic with the shortest downtime possible from the time the tail leaves the pay-off reel to the restart after notching. Main features of Siemens VAI installations are:

- The automation system ensures the automatic presetting of the head and tail end leveling as a function of strip grade and gauge
- Clecim® Direct Current Flash Butt 21-S welder, optimized to fulfill this requirement from tinplate products to DP and TRIP steels with its Weldamatic®

Control System. The unique design consists of a compact and sturdy core, where all operations are performed in record time.

- Clecim® new Laser Welder LW21H for heavy gauge for more demanding applications.

References

5-Stand tandem mill conversion to continuous operation for tinplate, sheet and automotive products at Sollac Atlantique Mardyck (Arcelor), France

Installlation of the latest version of the Clecim® FB 21-S welder, designed to weld strip gauges up to 7 mm (max. cross section: 12,000 mm²) for steel grades with yield strength of max. 1,200 MPa.

The welder is the most critical component of the continuous operation and furthermore for this application, due its very wide product range, the short entry downtime requirement due to increasing incoming thickness gauges.

Typical weld breakage rate is 0.1 % for continuous operation in this mill.

Conversion of a 4-stand tandem mill to a continuous 5-stand tandem mill for tinplate & sheet products for Essar Steel, India

The latest version of the Clecim® FB21-S welder is installed on the future CTCM in Essar steel. Integration tests were carried out in Siemens VAI workshop before the shipment. Those tests with customer product allow the qualification of the tuning and setting for quick & smooth start-up of the welder.

This new high end entry section combined with the addition of a 5th mill stand will allow Essar to achieve 220 % of the original coil-to-coil productivity and will give possibility of rolling strip down to 0.20 mm.

NEW DEVELOPMENT FOR LINE ENTRY LAYOUT

Very high throughput continuous tandem mills coupled to pickling lines (above 2 million tons per year) are often limited by the entry section downtime required for cutting and welding of the strips. For this specific need Siemens VAI has developed a new patented design of the entry section (Figure 3). This original design, with one additional accumulator and one stitcher, allows performing strip positioning and cutting in a separate phase from strip welding. Such an arrangement reduces the entry downtime by 35 %. As shown on Figure 2, depending on the product mix, this improvement provides an additional productivity of 15 to 30 %, and thus generates a very quick ROI.

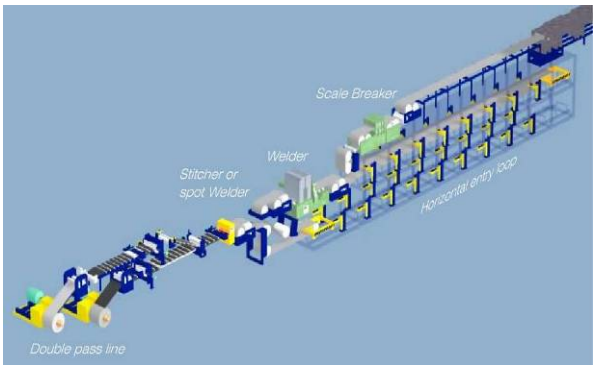

Figure 3: New high performance entry section

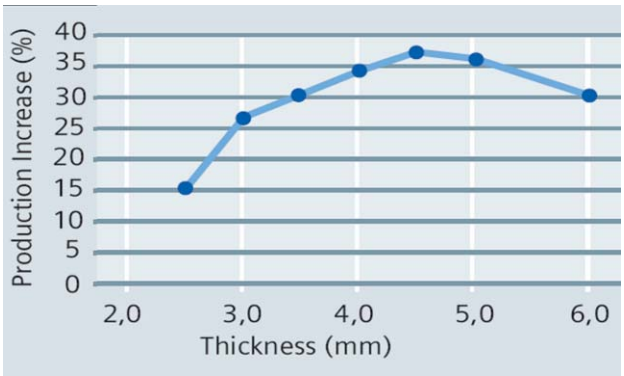

Figure 4: Production increase obtained in reducing the entry downtime by 35 %

COUPLING DEVICES AND ACCUMULATORS

When it is time to couple two existing lines that were built completely independently, the coupling devices have to be modular enough to accommodate virtually any possible layout. Very sturdy turning towers or helical turning rolls guarantee a maintenance free, self-centering and smooth operation without downtime. Accumulators can be installed at one or two levels, with two, four or six strands, and built underground, at floor level or even placed on the roof.

References

5-Stand tandem mill conversion to continuous operation for tinplate, sheet and automotive products at Sollac Atlantique Mardyck (Arcelor), France

With a pickling line and a mill in parallel and separated by one bay, the strip is diverted from the pickling section to the coupling accumulator through five strip turning devices laid in the ground. (Figure 5)

- The roll resistance to wear provides maintenance-free unit. The only motion is a rotation of the roll around its axis
- The strip centers by itself on the roll thanks to its special design

Figure 6 below shows the production learning curve after the coupling of the tandem mill. It took only 4 months to reach 100% of nominal production.

Figure 5: Arcelor Mardyck – turning tower

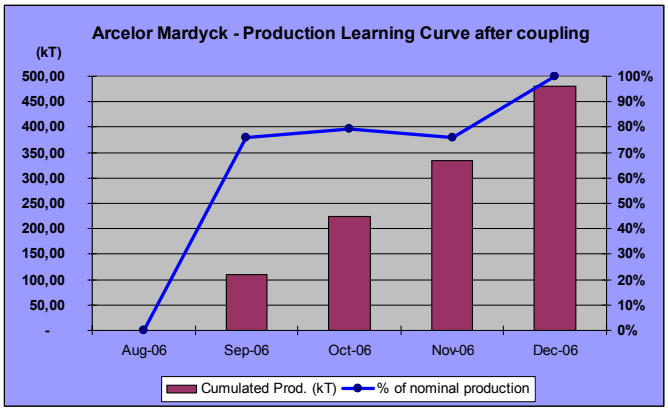

Figure 6: Arcelor Mardyck – learning curve

Conversion of a 5-stand tandem mill to a continuous 5-operation, Krakatau Steel, Indonesia

The looper building is located on the roof above the mill. Geometry of the tunnel structure was checked during a ground pre-assembly. Afterwards, the tunnel has been divided into 5 parts for lifting and re-assembled 25 meters above the ground over the mill roof.

- Construction work was implemented without disturbing the mill operation.

Figure 7: Krakatau Steel – looper on the roof

Conversion of a 4-stand tandem mill to a continuous 5-stand tandem mill for tinplate & sheet products for Essar Steel, India

The main purpose was to increase the steel strip production from 0.6 to 1.4 million tons per year, with the best performance in terms of gauge and shape tolerance. To achieve this, a completely new mill entry section with a 6-strand looper of 600 meter capacity has been installed, which is characterized as follows:

- Low inertia separator arms with optimized horizontal cam movement, main traversing winch and return winch
- Reduced overall length for high accumulation capacity

TANDEM MILL ENTRY DESIGN AND INFLUENCE ON THICKNESS PERFOMANCE

The mill entry section includes a centering unit between two bridle rolls, a guillotine shear and a three-roll unit for strip stabilizing in mill stand no. 1. The entry tension bridle roll position significantly improves the gauge performance on the rolled strip. In all cases the three-roll unit at mill entry has proved to be extremely useful and reliable to keep the strip centered into the mill.

References

5-Stand tandem mill conversion to continuous operation for tinplate, sheet and automotive products at Sollac Atlantique Mardyck (Arcelor), France

- The mill entry is designed for optimized gauge control required for the production of DWI grades and for eliminating strip breaks during the flying gauge change sequence.
- All existing controls were optimized during a cooperation program between Arcelor & Siemens VAI. As a result, the partnership activity yielded a 45% decrease in thickness non-quality cost and a 50% reduction of the thickness out-of-tolerance length.

Main Results:

Bridle in front of the mill for optimum response and **down to 0.7 % gauge** accuracy for DWI.

Figure 8: Arcelor Mardyck – mill entry

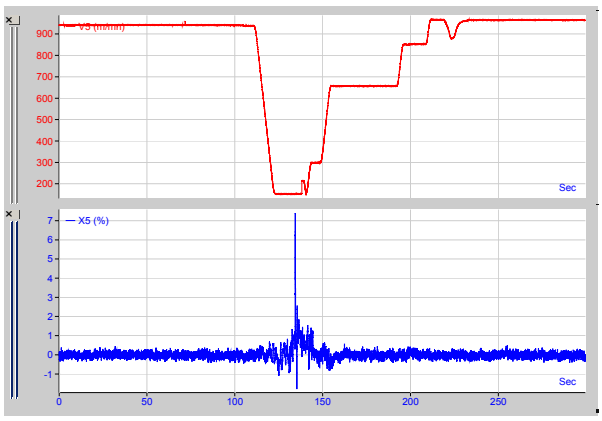

Figure 9: Arcelor Sidmed – gauge performance @ weld

5-Stand tandem mill coupled with pickle line for Mittal Steel (former Bethlehem Steel), Sparrows Point – USA

Focus on strip steering and coil telescope at the exit. The main focus of the rolling strategy is the optimization of the output and achievement of a high standard of product flatness. Speed guidance and flying gauge change are crucial factors in the case of a linked pickling-tandem line.

4-Stand 6-hi tandem mill coupled with pickle line for CORUS IJmuiden, The Netherlands

In the mill entry section a powerful bridle is installed just up-stream of mill stand no. 1 for a perfect control of the strip tension. This layout is combined with a new generation of thickness control, the advanced mass flow control.

Main Results:

A reduction of response time by a factor 3 can be reached by the use of the advanced thickness control for a thickness step in mill stand no. 1.

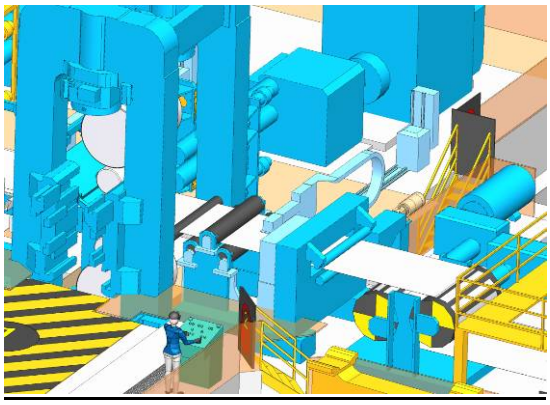

Figure 10: CORUS KW22 – mill entry

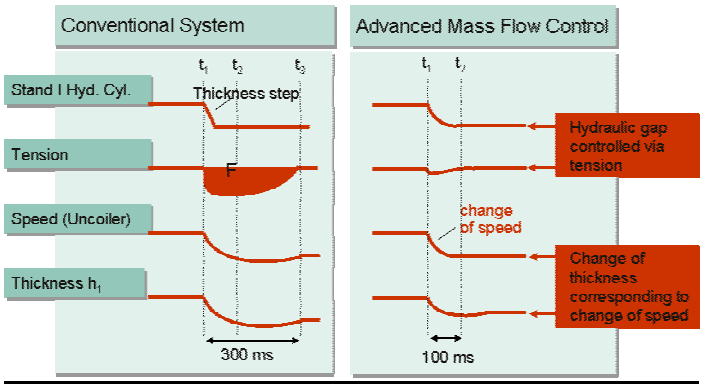

Figure 11: Advanced mass flow control

TANDEM MILL DESIGN FEATURES

Siemens VAI offers both 4-high and 6-high cold rolling mills. Both solutions bring specific benefits and our analysis of the customer's overall requirements defines the best possible technological solution and high mill flexibility for all products. The SmartCrown® roll contour associated with axial shifting of work rolls of 4-high mills or intermediate rolls of 6-high mills ensures enhanced flatness control.

References

5 stand 4-Hi SmartCrown® continuous tandem mill for voestalpine Stahl, Linz, Austria

The mill is dedicated to produce the latest high strength steel for automotive industry. The high motor, high roll force and powerful shape actuator with SmartCrown® overcome the difficulties to process this type of steel and to deliver the uppermost level of strip quality.

Figure 12: TCM, voestalpine, Austria

Figure 13: TCM 3D model

4 stand 6-hi mill coupled to PL for CORUS IJmuiden, Netherlands

With a product mix from soft steel to high strength steel, CORUS Ijmuiden will take benefit of the wide utilization range of 6-hi mill combined with easy operation. Versatile equipment able to support the future development of the advanced high strength steel grade will be installed.

FLYING GAUGE CHANGE AND SPEED OPTIMIZATION

Even though the right mechanical components are there, optimized throughput can be guaranteed only through process control features. To improve strip thickness control and flatness, the technological control system includes hydraulic gauge control (HGC), control loops for optimum thickness performance, tension control. In the continuous mode the two main functions are “Speed Optimization” and “Flying Gauge Change” (FGC)

- The Flying Gauge Change system permits widening the range of grades and sizes which can be welded together and is thus facilitating scheduling. Additionally the off-gauge lengths are shorter, which directly impact the yield performance. FGC must be capable of performing at high transition speed (>300 m/min) or low transition speeds required for some specific grades while keeping the strip gauge within required tolerances.
- The Speed Optimization module uses the line parameters, operating constraints and product data to optimize accumulator position and speeds in each section. The objective is to get the highest throughput at any time in all situations. The originality of the solution developed by Siemens VAI resides in the following features:
  - It does take into account all coils on the line, plus up to 10 upcoming coils, thus allowing to manage difficult situation induced by short coils
  - The modular design allows implementing it in an existing PLTCM with little modification of the automation system
  - In addition to controlling the line, it provides operation management with a set of indicators such as: percentage of bottlenecking per equipment and unused

capacity. Those indicators are valuable tools when it is time to evaluate the reliability of the equipment and prioritize capital investment projects.

References

Throughput optimization of 4- stand PLTCM, Arcelor Ste Agathe, France

In the tandem mill of Arcelor, Ste Agathe a throughput optimization module was installed in an existing plant, at first in an observation mode (passive). The following figure illustrates the result of the bottleneck identification module.

Productivity gains were assessed during two one-week test campaigns in summer 2006. The evaluations show that a potential throughput increase of 5.2 % can be reached using the following formula:

$$Perf = \frac{Predicted\_Length - Actual\_Length}{Actual\_Length} * 100$$

Other recent continuous tandem cold mills using the SIROLLCIS CM speed optimization are Baotou PLTCM in China, Dofasco PLTCM in Canada and HYSCO PLTCM in Korea.

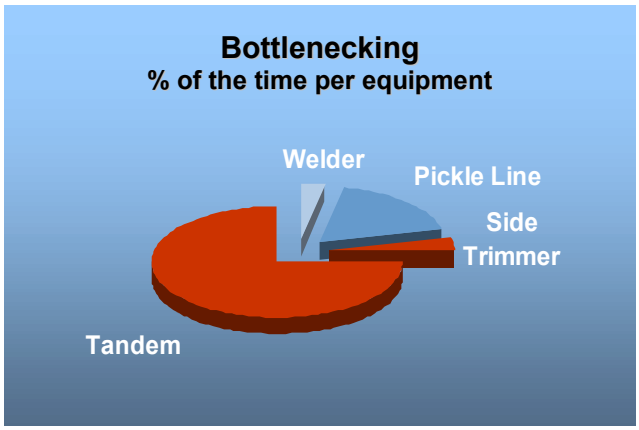

Figure 124: Bottleneck identification

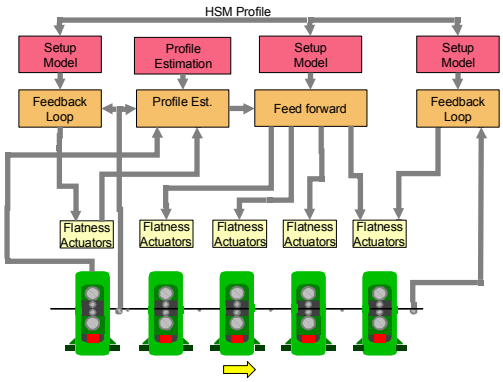

Figure 15: Schematic of flatness control through the mill

TANDEM MILL INSTRUMENTATION

The continuous process reduces and simplifies the interstand equipment configuration, so more space is available to implement the different gauges required by increasingly growing product quality requirement.

- In addition to thickness gauges (at least four), speed laser gauges are now required for better control of slippage and therefore gauge performance especially in the transitory periods (on both sides of the first and last mill stands)
- Profile, temperature and width gauges are then added to the application
- Planicim® shapemeter roll installed at mill stand No. 1 exit brings two advantages:
  - It permits mill presetting for optimized strip shape through the mill and thus smooth operation even if the entry profile of the strip is unknown
  - It helps improving steering through the mill and increasing speed
- Planicim® shapemeter roll or the SIFLAT® contactless measurement system installed at last stand exit for closed loop flatness control
- Automatic Surface Inspection System (SIAS), a Siemens VAI product, can be installed:
  - At the exit of the pickling line, to analyze the quality of the as-pickled strip before cold rolling and prevent further incidents caused by identified strip surface defects or edge cracks

- At the exit of last stand, providing an early identification of process-induced defects, permitting a swift correction and adequate downstream allocation or re-routing.

References

4 stand 6-hi mill coupled to PL for CORUS IJmuiden, Netherlands

Installation of a SIAS system at the tandem mill exit

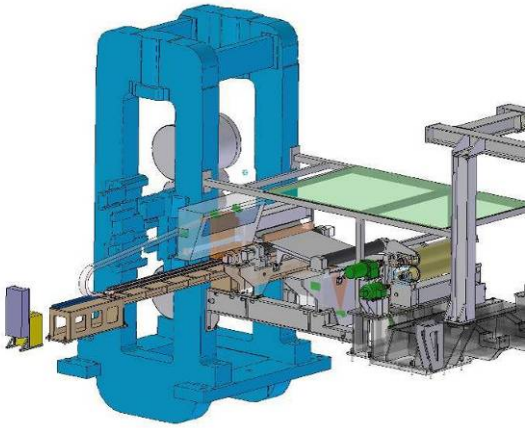

Figure 16: CORUS KW22 - SIAS installation diagramme

Figure 17: SIAS lighting system

COILING SECTION CONFIGURATIONS

The strip coiling section can employ a classical two-reel arrangement or a more compact carrousel reel. For both configurations an automatic sleeve feeding system can be implemented for thin gauges below 0.3 mm depending on mandrel diameter.
Also depending on the lay-out, the best inspection configuration can be considered – One side, two sides, on the fly, separate depending on the application.

References

Conversion of a 5-stand tandem mill to a continuous 5-operation, Krakatau Steel, Indonesia

- Two-reel configuration permits the existing equipment to be re-used in case of conversion and is the most suited for heavy gauge production with static switching system.
- In-line inspection. Both sides of the strip can be checked by means of a returning device. During shearing/switching operations an 8-meter sample is taken out from current coil and automatically positioned on the inspection table.

5 stand 4-Hi SmartCrown® continuous tandem mill for voestalpine Stahl, Linz, Austria

The installation of a two reel solution allows coiling the product mix which consist of a high degree of AHSS materials.

Figure 18: voestalpine Stahl - coiler

Figure 19: Krakatau Steel – inspection

New 5-stand tandem mill coupled to a pickling line, Tangshan, China

- Here the carrousel reel arrangement was installed, which allows for thin gauge production due to short distance and straight pass-line. This configuration is today often considered for new lines as it simplifies he coil evacuation lay-out and requires a reduced line length, but does not permit “on-the-fly” inspection so far. In addition the carrousel does not offer the operational flexibility of the two-coiler arrangement.

Figure 20: Tangshan – carrousel

OVERALL EQUIPMENT EFFICIENCY

In the race to obtain more throughputs in a coupled mill, equipment and automation have a great role to play. However one shall not diminish the importance of operation supervision, at various levels, i.e. production and maintenance.
In order to assist operational managers in this important task, Siemens VAI automation solution for PLTCM includes a dedicated TPM module (TPM stands for Total Productive Maintenance). This module objective is to provide on-line, reliable information regarding availability, throughput and quality. It calculates in real time the OEE (Overall Equipment Efficiency), which is a compounded indicator gathering three aspects:

- Quality, i.e. the ratio of product with quality within acceptable limits
- Line availability, i.e. the ratio of available time to produce
- Performance, i.e. the ratio of achieved throughput over calculated capacity

Such a tool was or will be installed in several plants such as ESSAR, TISCO, CORUS, and it has proven to be extremely helpful to any level of operation & maintenance personnel. It provides a clear and reliable picture of potential savings.

Additionally it is a good monitoring tool to assess the efficiency of preventive or corrective maintenance actions. The picture below is the main dashboard for operators and foremen. The module also comes with a comprehensive suite of reports focused on delays management & quality losses.

Figure 21: Overall equipment efficiency – main dashboard

CONCLUSION

Continuous tandem cold mills represent a very attractive configuration for cold strip production. A continuous or coupled mill is also a complex line that integrates a series of unitary components, each and every link of the chain needs to perform in a sustainable manner in order to provide the expected goals in terms of throughput and quality.
This paper shows through real life examples how Siemens VAI SIROLL$_{CIS}$ CM systems combine equipment and process control to achieve these goals and represent modern solutions for continuous cold rolling.