Latest Equipment and Technology Highlights in Endless Cold Rolling Mills

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VAI has successfully developed and installed a number of technical solutions and packages for continuous cold-rolling tandem mills and coupled pickling-tandem lines, including:
specific technological solutions such as welders, flatteners, shears, tension reels in addition to engineering tools for optimized plant layouts and operational practices; process control packages featuring fast control techniques, physical models, operator interfaces and sequence control.
In this paper the design features of such technical solutions and packages are discussed for improved cold-rolling results in addition to project examples where these solutions were implemented.

INTRODUCTION

It is well documented that continuous tandem-mill operation offers the greatest benefits in terms of productivity, product yield and quality. More than 200 cold-rolling tandem mills are currently in operation worldwide of which approximately 70 are either coupled to a pickling line or are fully continuous. More than half of the existing continuous cold-rolling mills were implemented by VAI, underlying the immense amount of experience acquired towards determining the optimum solution for each mill and product mix. New equipment solutions and technologies are now available examples of which are outlined in this paper:

- Strip feeding and welding sections for the SOLLAC Atlantique Mardyck (France) continuous mill (ARCELOR Group)
- Supply of accumulators and strip-turning towers
- Installation of mill-entry steering and automatic shape control
- Strip-edge-drop control at WISCO, China
- Line pacing and flying gauge change for throughput optimization at Bethlehem Steel (USA) and Sidmed (ARCELOR Group), France
- Coiling sections with two reels or carrousel configuration at Sollac Mardyck (France), Pangang (China) and Krakatau Steel (Indonesia)
- Strip inspection at Krakatau Steel (Indonesia).

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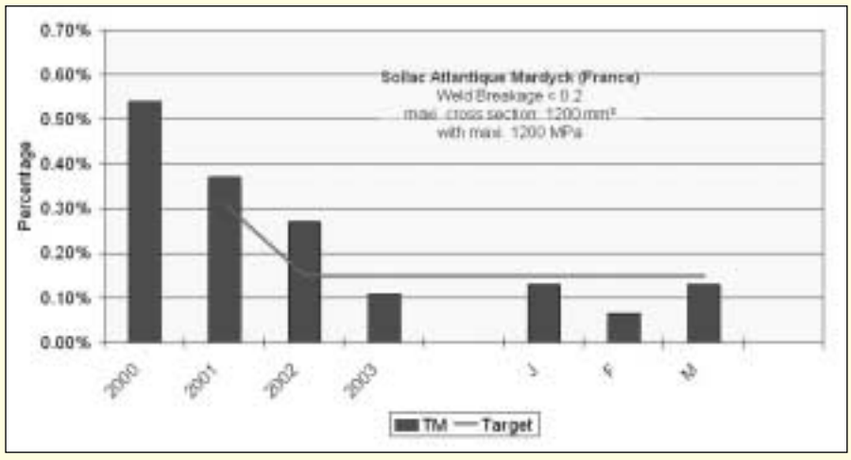


Figure 1: Weld-Breakage Percentage, SOLLAC Atlantique Mardyck (ARCELOR), France.

EXAMPLES OF TECHNICAL SOLUTIONS

Strip Feeding and Welding Section

Due to its high impact on line performance the strip feeding and welding section is designed for high-feeding pacing and rollable welds, regardless of the product grade and size. The feeding section is fully automatic with a total downtime of less than an average of 100 seconds from the time the tail leaves the payoff reel to the restart after notching.

Features

- Automatic presetting of the head and tail leveling as a function of the strip gauge and grade
- Installation of direct current VAI Clecim Flash Butt 21-S welder which fulfils the requirements from tinplate products to dual phase and TRIP (Transformation-Induced Plasticity) steels on the basis of the Weldamatic® Control System. The design is characterized by its compact and sturdy core where all operations are performed in record time.

Project Example—SOLLAC Atlantique Mardyck (ARCELOR), France

- Conversion of a 5-stand tandem mill to a continuous mill for the production of tinplate, sheet and automotive products
- Installation of the VAI Clecim Flash Butt 21-S welder, designed to weld strip gauges up to 7 mm (max. cross section: 12,000 mm_) in steel grades with a maximum of 1,200 MPa yield strength.

The welder is the most critical component for the continuous operation of the cold mill, particularly with respect to a wide product range, short entry downtime and an ever-increasing reduction performed by the tandem mill. Figure 1 shows the weld-breakage percentages for sheet products from the mill start-up in 2000 to March 2003.

Project Example—Krakatau Steel, Indonesia

- Conversion of 5-stand tandem mill to a continuous mill for the production of tinplate and sheet products.

- Installation of VAI Clecim Flash Butt 21-S welder designed to weld strip gauges up to 5 mm.

Following the mill re-start on December 28, 2002, more than 3,000 welds were rolled without a single weld breakage in the mill.

Accumulators and Strip Turning Towers

Installation of very sturdy turning towers guarantees 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, or built underground, at floor level or even placed on the roof.

Project Example—Sollac Atlantique Mardyck (ARCELOR), France

The strip is diverted from the welding section to the perpendicular entry accumulator through a 90° strip-turning device, built in the ground. As there is no other movement than the roll rotation itself, maintenance requirements are minimized. Self-centering of the strip is automatically carried out due to the special design of the rolls.
Due to space constraints a 6-strand design was chosen with a total capacity of 600 meters to compensate for the entry downtime. Low-inertia separator arms with optimized horizontal cam movement ensure a smooth arm opening and closing. Runways were installed on both sides of the structure to enable easy access and maintenance.

Project Example—Krakatau Steel, Indonesia

The looper housing is located on the roof above the mill. The geometry of the tunnel structure was checked during a ground pre-assembly. The tunnel was then divided into 5 sections for lifting and was re-assembled 25 meters above the ground and over the roof of the mill. Construction work was implemented without disturbing routine mill operations.

Project Example—Sidmed (ARCELOR), Spain

- Conversion of a 5-stand tandem mill to a continuous mill for the production of sheet and exposed automotive products.
- Increase in steel sheet production from 1.2 to 2 million tons per year through the installation of a new mill entry section with a double 4-strand looper and with a 675-meter capacity accumulator
- Installation of low-inertia separator arms with an optimized vertical cam movement, including a main traversing winch and return winch
- Careful arrangement of the mill-entry steering unit in relationship to the entry tension bridle roll for improved gauge performance.

Figure 2: Turning Tower at Sollac Atlantique Mardyck, France.

Figure 3: Looper Installed on the Roof at Krakatau Steel, Indonesia.

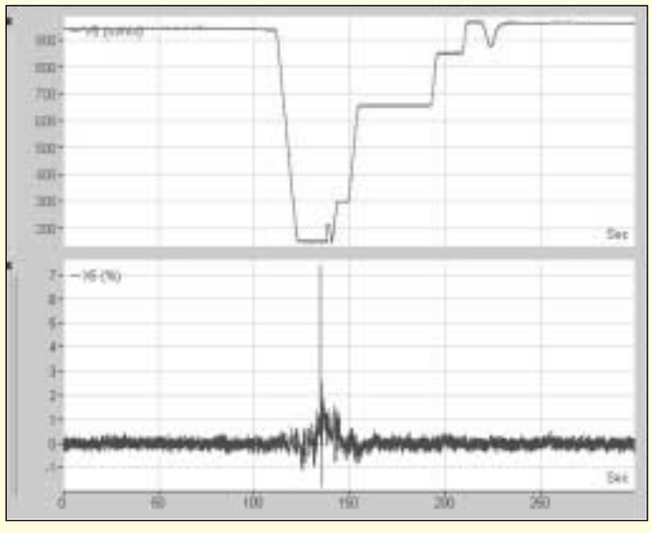


Figure 4: Gauge Performance at Sidmed, France.

The installation of a three-roll unit at the mill entry section has proved to be extremely reliable for keeping the strip centered into the mill.

Project Example—Sollac Atlantique Mardyck (ARCELOR), France

The mill entry section includes a centering unit between two bridle rolls, a guillotine shear and a three-roll unit for strip stabilization in the roll bite of stand No. 1. The mill entry is designed to ensure an optimized gauge control which meets the requirements for the production of DWI (drawn and walled iron) grades and for minimized strip breakage during the flying gauge change sequence. Positioning of the bridle in front of the mill ensures fast response and a gauge accuracy down to 0.7% for DWI grades.

Project Example—Bethlehem Steel, Sparrows Point, MD, USA

(5-Stand Tandem Mill Coupled with a Pickle Line)

The main focus of the rolling strategy is to increase the output and to achieve higher standards of product flatness. Speed guidance and flying gauge changes are crucial factors for an ideal performance in a linked pickling-tandem line. A strip steering unit and coil telescope were installed at the exit section.

Strip Edge-Drop Control and Edge-Crack Control

As none of the conventional mill designs (6-high or 4-high) are capable of assuring perfect strip "squareness," edge-

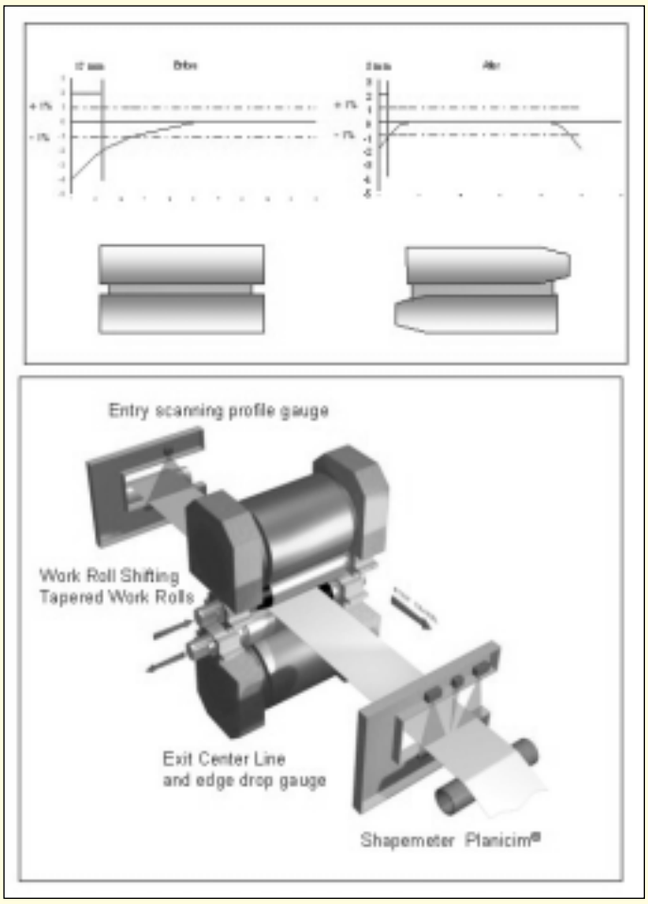
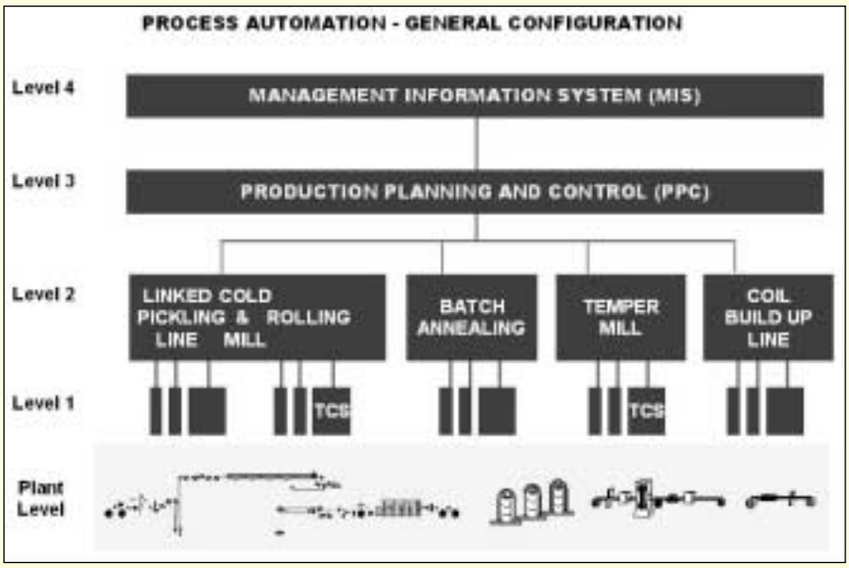


Figure 5: Edge Drop Control at WISCO, China.

Figure 6: General Configuration of Automation System Installed at Bethlehem Steel, USA.



drop compensation with tapered work rolls—which have a direct effect on the strip edge profile—are required for some steel grades such as low silicon electric steels. Work-roll shifting on the first mill stands adjusts the roll taper in relationship to the strip edge and controls the strip-edge profile in conjunction with a strip-edge-profile gauge.
For hard sheet grades and tinplate products work-roll shifting with tapered rolls in the intermediate stands could also allow a decrease in Hertzian stress between the edge rolls and thus reduce the frequency of edge-crack occurrences.

Project Example—WISCO, China
(Modernization and Coupling of Pickling Line and 4-Stand Tandem Mill)

Line Pacing and Flying Gauge Change Systems
Even with the right mechanical components high throughput rates can only be guaranteed with advanced process-control systems. To improve strip-thickness control and flatness the technological control system must include hydraulic gauge control (HGC), control loops for optimum thickness performance and tension control. In continuous cold rolling the two critical functions are “line pacing” and “flying gauge change” (FGC).
The Line Pacing/Plant Coordination Model developed for Bethlehem Steel utilizes the line parameters, operating constraints and product data to optimize the accumulator position and speeds in each section. The objective is to achieve the highest throughput at any time in all situations. This function requires an excellent weld and product tracking throughout the line.
In the same way, the quality of the flying gauge change system enables a broader range of grades and strip sizes to be welded together which facilitates scheduling. Also, the off-gauge lengths are shorter, which directly has an impact on yield performance. FGC must be capable of performing at high transition speeds (>300 m/min) or at low transition speeds required for certain grades while keeping the strip gauge within the required tolerances.

Reference Example—Bethlehem Steel, Sparrows Point, MD, USA
- Installation of completely new automation architecture
- Installation of VAI’s LinkMaster® to optimized the line speed for a maximized throughput.

MAIN RESULTS

Thickness (0.254–2.54 mm)	99.17% of strip length
Tolerance	1.2–0.8%
Off-Gauge Lengths	5–8 m
Flatness (thickness: 0.254–2.54 mm at tolerances of 15 to 9 I-Units)	99.88% of strip length

Reference Example—Sidmed (ARCELOR Group), Spain
- Integrated of VAI automation architecture within existing system
- Installation of VAI Clecim's "CORUM® Cold-Mill Presetting Model".

Main Results
Following the revamp an average of 10 meters off-gauge strip length could be achieved within a 2.5% thickness tolerance. The mill surpassed its previous

productivity level 2 months after resuming production and broke a 3,045 ton daily record 4 months after the first coil was produced.

Tandem Mill Instrumentation

The continuous rolling process simplifies and reduces the interstand equipment so more space is available to produce different gauges for a broader product mix. Other important factors are as follows:

- In addition to thickness gauges (at least four), laser speed gauges are now required for better control of slippage and therefore gauge performance, especially during the transitory periods (on both sides of the first and last stand)
- Profile, temperature and width gauges are also installed
- A Planicim® Shapemeter roll installed at the exit of mill stand No. 1 promotes an improved flatness control for the following reasons:
  - Permits mill presetting to ensure an optimized strip shape and smooth operation, even if the entry profile of the strip is unknown
  - Enables careful control of the strip speed and steering through the mill.

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 installed for thin gauges below 0.3 mm, depending on mandrel diameter. Also, depending on the mill layout, one side, two sides as well as on-the-fly strip inspection set-ups are possible.

Project Example—Krakatau Steel, Indonesia

- Installation of a two-reel configuration which permits the existing equipment to be re-used in case the mill is converted to a continuous mill. This arrangement is most suited for heavy gauge production with a static switching system.
- Both sides of the strip can be inspected by means of a turning device. During shearing/switching operations, an 8-meter sample is taken from the current coil and automatically positioned on the inspection table.

Project Example—Panzhihua, China

(Modernization and Coupling of Pickling Line and 5-Stand Tandem Mill)

A carrousel reel arrangement was installed which is better suited for thin gauge production due to short distances and a straight pass-line. This configuration is generally employed for new lines as it simplifies the coil evacuation layout and requires a shorter line length, but does not permit "on-the-fly" inspection so far. The carrousel reel arrangement, however, does not offer the operational flexibility of a two-coiler arrangement.

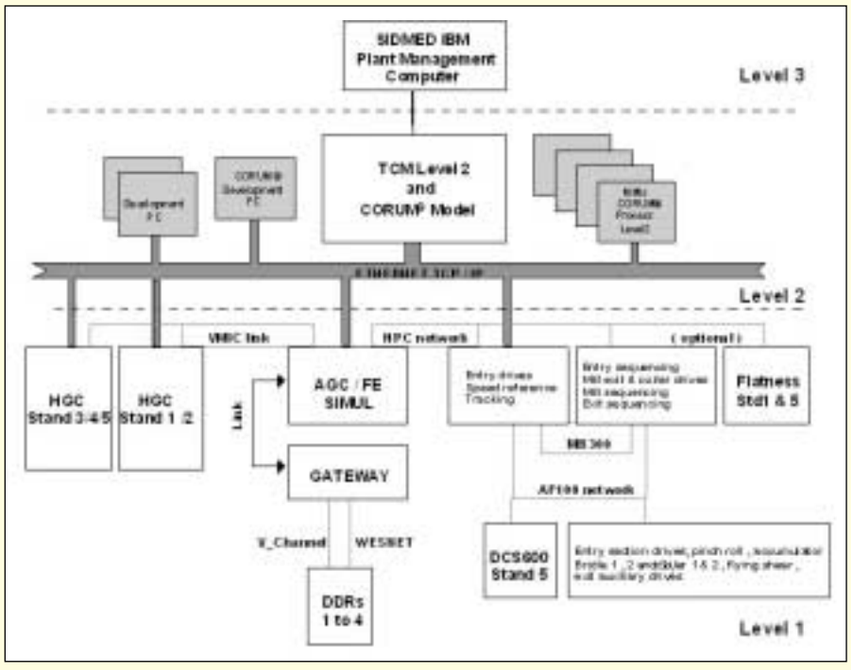


Figure 7: Automation Architecture at Sidmed, France.

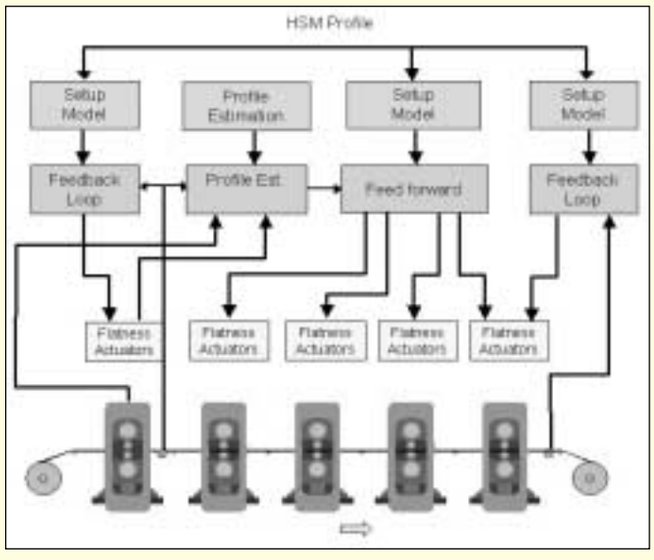


Figure 8: Flatness Control.

Figure 9: Strip Inspection at Krakatau Steel, Indonesia.

Figure 10: Strip Carrousel at Panzhihua, China.

CONCLUDING REMARKS

This paper has discussed various features and aspects of state-of-the-art endless-cold-rolling equipment and technology. In accordance with the increased market demands for ultra-high-strength steel products, VAI Clecim (a company of the VAI Group), which has pioneered advanced actuators for profile and flatness controls in rolling mills, is currently designing mill stands capable of rolling both ultra-low carbon and ultra-high carbon steel grades.