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NEW PRODUCTS AND TECHNOLOGIES FOR HIGH PRODUCTIVITY STAINLESS STEEL STRIP ROUTE*

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Abstract
Price pressure is a real challenge on the stainless steel market. With market globalization, increase production capacity and exorbitant raw material, the margins are squeezing for stainless strip producers. Primetals Technologies offers a wide range of advanced technological solutions to secure the margins of our customers. Our solutions, implemented with professional project management, allow an optimum coil to market time, securing then the return on investment for the investor.
Among the possible lever used to optimize the production route, one drastic step can be made to cut rolling time and cost by replacing the common 20-Hi mill stand reversing process by state of art high capacity X-HI® stands in continuous rolling line. Other source of savings can be implemented by integrated several process steps together (rolling, annealing, pickling, skin passing), achieving then savings on stocks and logistics while coil processing is reduced to fraction of hour. Additional solutions can also be implemented on the new, as well as existing line, like maintenance free solid state laser welder, skin-pass and tension levelers, in-line inspection system coupled with process and quality management system.
Keywords: Rolling; Stainless steel; Z-high; X-HI.

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1 INTRODUCTION

Price pressure is a real challenge on the stainless steel market. With market globalization, increase production capacity and exorbitant raw material, the margins are squeezing for stainless strip producers. Primetals Technologies offers a wide range of advanced technological solutions to secure the margins of our customers. Our solutions, implemented with professional project management, allow an optimum coil to market time, securing then the return on investment for the investor.

2 COLD REDUCTION: THE INTEGRATED LINE CONCEPT, ADVANTAGES AND LIMITATIONS

For decades, the main cold reduction tool in the stainless steel flat product industry has been the 20-Hi reversing mill. In the past twenty years, in-line rolling has developed to the point of becoming today a standard concept for new plants. Starting with a single-stand in-line rolling in NYBY in Sweden, the concept rapidly evolved after first successes, into tandem mill integration, as pioneered in J&L and UGINE Isbergues (LC2i) in the late 90's. Since then, a whole variety of different processes were successfully implemented: rolling on black coils -unpickled- hot band, rolling on hot band after pickling, such as in LC2i in Isbergues or rolling on an annealed and pickled hot band. Some integrated lines –such as in Avesta-Polarit, Outokumpu, were also combining twice rolling processes on the same line, with re-processing a significant share of the production through the same line.
More recently Primetals Technologies installed a 4 stands Power X-HI® mill integrated in the rolling annealing and pickling line at Baosteel Fujian Desheng which started production in February 2015.
A step forward has been achieved with the execution of a new contract to supply a 5 stands Power X-HI® continuous rolling line for Beihai Chengde Stainless Steel. The the first coil has been produced at the Beihai plant in Guangxi Province in late December 2015. The cold test was performed within 17 days and the first coil produced within only three months after completion of equipment installation, to the satisfaction of Beihai Chengde Stainless Steel. With a capacity of 600,000 tons per year, the rolling mill having a rolling speed of 400 m/min is the fastest of its kind in China. To ensure the most reliable continuous process, the line entry section is equipped with Primetals Technologies heavy laser welder with ability to weld the most difficult grades from 1.0 mm to 5.0 mm, while entry and exit looper ensure a smooth, independent and continuous rolling process from entry and exit ends.

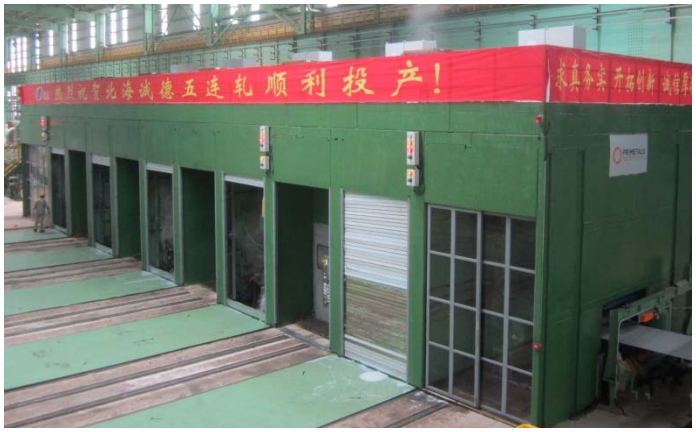

Figure 1. CTCM, Beihai Chengde, China

For a machinery builder, the issue is to design a mill withstanding the constraints of continuous operation, and then to reliably include it into either a hot-rolling annealing and pickling line (HAPL) or a cold-rolling APL (CAPL), or a combination of the above.
As for the skin-pass mill, its integration into CAPLs has become common, as, for example, implemented by Primetals Technologies in ACESITA, Brazil, or POSCO APF line in Pohang, Korea.
The advantages of any integrated process in the steel industry are well known: reduced coil inventory, reduced production time from order to delivery, improved yield through fewer handling steps and process parameter consistency, reduced operating cost, reduced investment per ton produced for large capacities.
Some recently introduced stainless steel grades seem to derive specific process advantages from the continuous in-line route. For example, avoiding inter-pass cool-down brittleness, or permitting additives in the mill coolant not yet permitted in the reversing mills, because of the staining potential during intermediate coil storage.
Virtually all existing in-line applications use the “Z-high” stand mill type, originally invented by T. Sendzimir in the 1950’s: a special 6-Hi mill with driven intermediate rolls and small – approx. 140 mm diameter – work rolls, equipped with side support roll assemblies on front and back side of work rolls. Several variations of the original concept have since been developed by rolling mill manufacturers.
The specific in-line rolling limitations for stainless steel production with such a mill, whether single stand or in tandem, can be listed as follows:

- Coil reduction is capped
    - as compared to 20-Hi reversing mills: for most lines from 25% up to 60%, with a technology limit near 75%, depending on the number of mill stands, strip size and grade.
    - reprocessing twice in the line is however possible and is indeed in several instances part of the original design.
- Surface aspect control: surfaces produced by integrated lines are confined to most common aspects such as 2E or 2B, excluding 2R bright finish and all special mechanical surface conditioned finishes.

In summary, integrated lines are economically suitable for main stream production, while bright-annealed strips, the thinner range of the production and specialty alloys will still come out of the conventional reversing mill route.
The integrated lines include the latest technology addressing environmental discharge issues and minimizing energy usage. They incorporate chemical and acid recovery systems to reduce quantities requiring neutralization prior to final discharge, heat recovery systems to minimize fuel usage in furnace section, and fume treatment plant to minimize discharges to atmosphere, particularly of NOx.
In comparison to separate processes, the integrated line also offers benefits in reducing the electrical energy consumption. These savings result directly from the elimination of production processes, and coil handling and storage requirements.
More specifically, the energy and consumables savings are achieved on:

- Reversing Cold Mill Coiler & Uncoiler motorization energy,
- Coil residual heat from rolling process before entering furnace,
- Lower and steadier rolling speed, reducing acceleration/deceleration energy,
- Less energy spent on coil handling,
- Better yield at head and tail ends, lowering scrap re-processing through melt shop,
- More efficient fume exhaust thanks to lower run speed and minimized extraction surface,

- Savings on paper and banding strips used for the coils between RCM and downstream processes.

Infrastructure investment and maintenance are also reduced, per ton produced, by:

- Drastic reduction of the number of coilers and X-Ray gauges,
- Suppression of coil handling equipment,
- Reduction of concrete, steel structures and building infrastructure,
- Less running inventory,
- More compact layout.

Latest generation of high productivity rolling line on the market are now featuring 5 Power X-HI® mill stands and have capacity of more than 600,000 tpa (Figure 2).

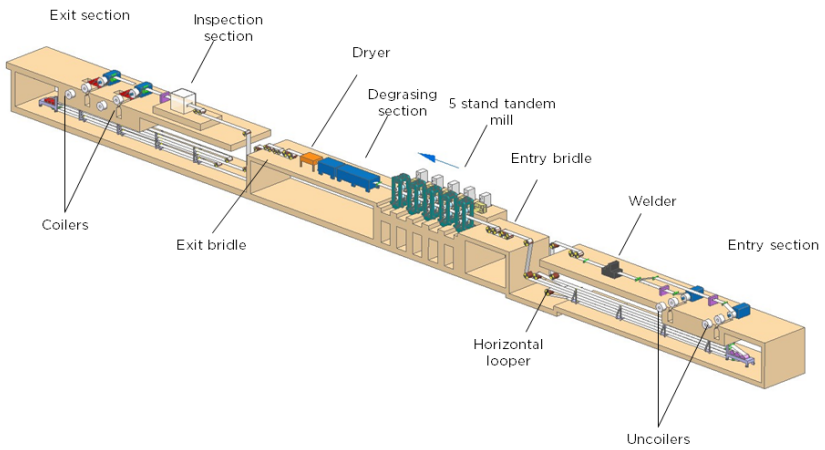

Figure 2. 5 stands Power X-HI CTCM with laser welder

2.1.The 20-Hi reversing mill

In most cold rolling plants for stainless steel, 20-Hi mills do the entire cold reduction work.

Perfectly adapted to cold rolling hard material down to thickness less than 0.2 mm, the 20-Hi mechanical technology, however, has only marginally evolved since its introduction in the 1950's. Innovations concentrated on flatness actuators improving control capability but also increasing complexity, housing design such as the "split housing concept", and ancillary functions such as oil wiping devices or roll change. Primetals Technologies has recently introduced the non-contact flatness measuring system "SIFLAT" that acquired strong acceptance on such mills: in addition to its simple operation and maintenance, it avoids the risks of altering the strip surface, particularly for sensitive material such as 2R (BA) bright finish.

What has not yet been addressed by the 20-Hi evolutions?

- The fixed small work roll diameter limits reduction rates on first passes, especially for thick incoming material,
- The speed stays limited on last passes, where productivity would require it most, for quality reasons,
- Flatness actuators and mechanical arrangement still need costly attention and skills,
- Speed – and thus productivity – is also limited by cooling efficiency constraints,
- The use of pure mineral oil is costly in itself, as compared with emulsion,
- Its proven inadequacy for continuous rolling in an integrated line.

2.2 The Power X-HI® mill

The Power X-HI® mill (Figure 3) patented technology, recently implemented by Primetals Technologies is accepting an increased range of roll diameters to optimize the average reduction rate per pass. Strip and roll cooling are also improved, to push further the thermal barrier still limiting speed and reduction.
In designing and operating a cold mill, one faces the main rolling process factors here-after listed:

- The roll force limit, and the corresponding linear Hertz pressure,
- The work roll diameter range, and work roll material elastic deformation,
- The generated heat, related to the strip and roll cooling capacity of the mill coolant system, particularly for small work rolls,
- The rolling stability (neutral point position), combined with entry and delivery strip applied tensions,
- The rolling torque that can be transmitted to the work rolls,
- The coolant behavior and chemical stability in the “rolling bite”, and its local effect on bite friction.

Most of the above is linked to high- and low-speed ranges, and in some extreme cases to strip flatness conditions.

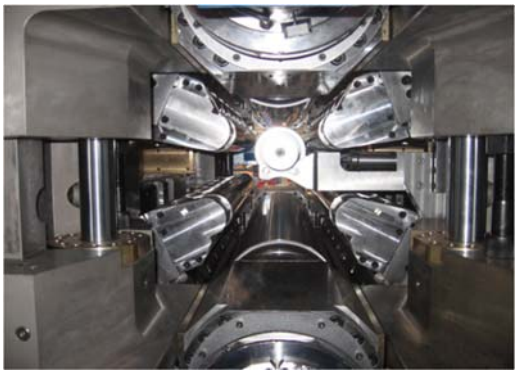

Figure 3. Power X-HI® CTCM

A typical cold reversing mill for stainless steel may accept an incoming product up to 8.0 mm thick, and at a different time, produce a finished strip at 0.3 mm or less, with the same work roll diameter. For first passes on heavy gauge, a large roll diameter would be preferable to avoid the draft limitation and increase cold reduction, while a small work roll diameter is desirable for the last passes of the thinner gauge range.
The mechanical concept has been re-developed to take into account Primetals Technologies long experience in continuous tandem operation: intermediate rolls are now mounted into a sturdy shifting chock assembly, the stabilizing rolls have been re-arranged into a convenient modular design with a strong and reproducible posi-tioning system.
Rolling geometry has been optimized to slightly increase the actual work roll di-ameter range.
In addition, lubrication and cooling (Figure 4) have been entirely re-designed for improved efficiency, in both neat oil and emulsion configuration. This mill is available in both tandem configuration, for in-line rolling, as well as the main component of a new or revamped reversing mill, for speeds up to 800 mpm.
And finally the work roll supporting and dismounting system has been designed to allow in-rolling flying roll change associated with optimised flying gauge change

control (patented technology) to be in position to optimise both yield and product performances.

2.3 Cold-rolling lubricant and coolant in Power X-HI®

Pure mineral oil is the traditional – and still most used – rolling lubricant for both reversing and tandem applications. Water-based emulsion, once considered as unsuitable for cold rolling stainless steel, is gaining interest, offering improved mill cooling performance at high speed, and less costly subsequent strip cleaning.
For slow in-line single stand or tandem mills, neat oil is, however, still preferred in many cases. For the near future, synthetic lubricants, polymer-water-based, could be promising: their application range may increase for stainless steel cold rolling when their stability and operating temperature widens. Primetals Technologies also benefits from the efficient range of its in-house Schneider filters fit for numerous mill coolant applications.

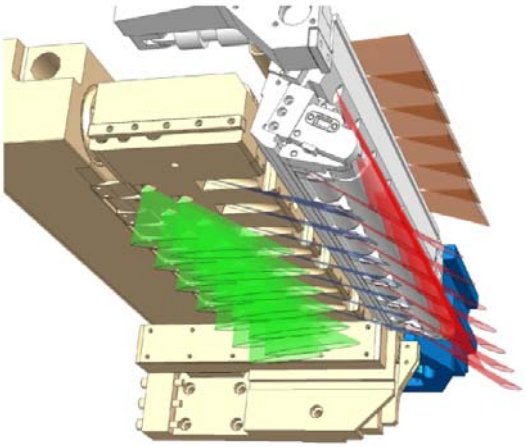

Figure 4. X-HI® patented cooling configuration for 18-High stand

2.4 Concept for efficient and economic production

In the standard processing routes, the stainless hot rolled material is firstly annealed and pickled, then cold rolled in a 20-Hi mill down to the desire thickness. Final annealing, pickling and skin passing are then implemented. In some cases, for thinnest gauges an intermediate annealing and pickling is required inducing a second passage in the rolling mill. Perfectly adapted to high reduction down to thin gauge, the “classical” reversing rolling through 20-Hi still has several drawbacks like high yield losses due to the unrolled portion, time consuming threading, reversing process and limited cooling efficiency.

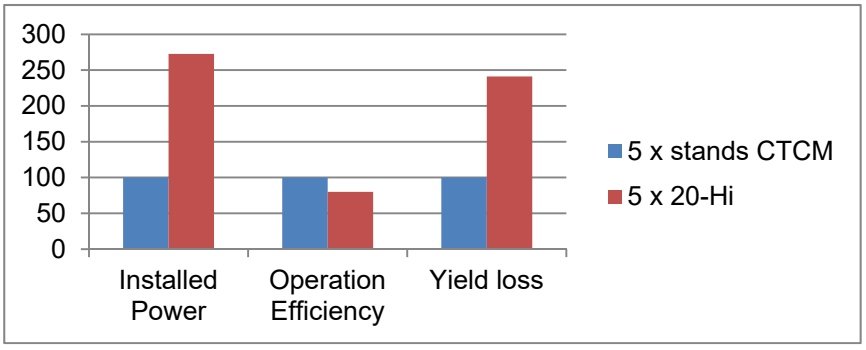

Figure 5. Comparison between CTCM and 20-high on a basis of 100

As precondition, the processes need to remain separate, as the required flexibility (working with two pickling and annealing lines for different products) cannot be achieved with integrated rolling, annealing and pickling line. The challenge was then to streamline the rolling process in order to save the margins

- Low Yield loss
- High efficiency in energy & operation
- Accessible technology to maintain good working level with the local set-up

To ensure an endless feeding of the mill with strip, the line entry accommodates a double pay off reels, processors, a laser welder and 6 strands looper. The entry tension is controlled by 4-rolls high tension bridle unit.
A cleaning section, installed just after the mill, removes the oil residues from the strip, with combination of high pressure hot water, steam and brush scrubber, making alkali useless.
Following this section, the 6 rolls bridle and the exit looper give the ability to completely separate the coiling speed and tension between mill exit and coiling section. This enables surface inspection while keeping continuous rolling operation thus minimizing strip losses.
The exit section features also a typical design with rotary shear, twin coiler arrangement and double paper unwinders.
This line arrangement combining flexible operation and standard design made of standardized components from market will ensure very high operation efficiency, high reliability combined with low operation costs.

3 KEY SOLUTIONS TO IMPROVE YOUR PRODUCTION EFFICIENCY

3.1 SIFLAT non-contact flatness measurement system

For most surface-sensitive steel products, each roll is a potential source of defects to be carefully monitored. Primetals Technologies measuring system (Figure 6) has found an excellent application field in stainless reversing mills: as mentioned earlier, users particularly appreciate its non-contact feature as compared to flatness measuring rolls. As side benefit the non-contact static sensor ensure a longer lifetime and then a lower operation compared to conventionnal system.

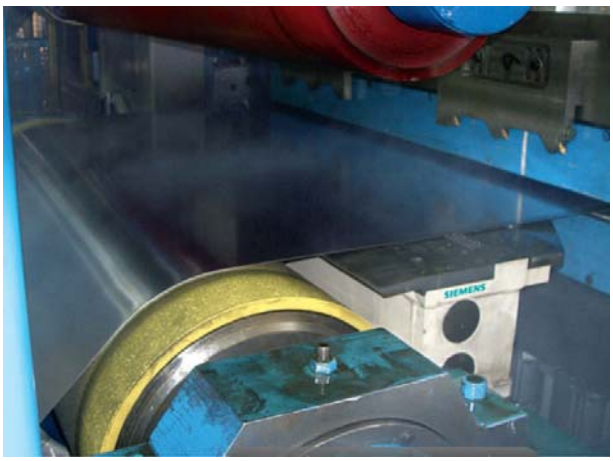

Figure 6. SIFLAT non-contact flatness measurement system installed on a 20-Hi mill

3.2 A new generation of laser welders

While Primetals Technologies has extensively been using–and is still- well honed plasma MIG welder from reputable companies in stainless steel lines, its own line of welders for carbon and stainless steel was extended in the past five years to the solid state laser welders with the so called Asolid laser welder generation (patented technology).
Developed from a blank sheet, and taking into account its vast experience in this field, Primetals Technologies light-gauge (LW21L) and heavy gauge(LW21H) laser welder range for cold-rolled strip uses the same laser source both for cutting and welding, to obtain a constant clean cut with no blade to sharpen, within a short time cycle. Their application to silicon and stainless steel is considered economically viable and technically interesting, and will improve in the future with the wider spread of laser sources with simpler maintenance.
In the specific case of the multistand in line rolling mill, presented above, the heavy-gauge laser welder afford a great benefit by improving the rolability of the weld and securing the continuous operation.

Figure 7. Laser welder installed at Beihai Chengde during commissioning of the line

3.3 Automatic surface inspection

SIAS® automatic surface inspection devices (Figure 8) by Primetals Technologies, with its single linear camera design and powerful classification engine, are well suited for detecting, classifying and grading the variety of defects from many different surface aspects of a stainless steel product.
Many references successfully operate at each manufacturing stage of the stainless steel flat product: on hot steckel mills, after hot rolled pickling, after skin-pass rolling in a cold APL, and at the exit of a bright-annealing line. Instant feedback on surface quality pays back in less than a few months.

Figure 8. SIAS® inspection system

3.4 Test cold rolling mill

Primetals Technologies maintains in its workshop in Montbrison in France, a narrow-band test cold mill in operation (Figure 9), fully instrumented and recently upgraded with the latest AGC and automation system. A complete range of work and back-up roll diameters and configurations, several coolant circuits and powerful bridles make it a versatile tool for experimenting near-industrial rolling conditions at actual speed and linear roll force. More specifically, the testing facility has been used to tune the emulsion-based rolling process model.

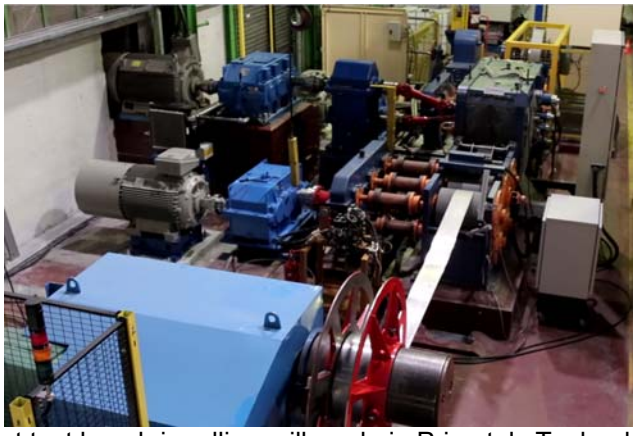

Figure 9. Pilot test bench in rolling mill mode in Primetals Technologies France

4 CONCLUSION

Primetals Technologies plays a significant role in the continuous in-line rolling of stainless steel, with the supply of the UGINE LC2i in Isbergues, France, started in 1999, the implementation of the automation and drives of the RAP5 of Outokumpu in Tornio, Finland, the mechanicals of the DRAP line installed at LISCO near Guangzhou, China and the recent Baosteel Desheng and Behai Chengde lines also for China. The new introduction by Primetals Technologies of the Power X-HI® mill family is proving that old concepts can always still be successfully re-thought, with the drive of stringent market demands. Primetals Technologies enjoys a wide experience in large processing line integration with mills and automation, together with the in-house mastering of other key components such as strip welders, flatness and surface quality sensors. This added technology value does translate into economic benefits to the steel producers.

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