QUALITY AND PRODUCTIVITY IMPROVEMENTS IN COLD STRIP PROCESSING OF STAINLESS STEEL[1]

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Abstract
Recent and upcoming cold rolling evolutions are presented with their influence on overall process route available options, in the arrangement of a cold mill workshop at the beginning of this century. In addition to well known economic advantages such as inventory reduction, shortening of order-to-delivery time and yield improvement, the integration of cold rolling into an Anneal and Pickle line brings for some new steel grades definite process treatment advantages. In parallel, the reversing mill becomes an ideal specialty complement, with a strong market demand for widening its process flexibility.
Key words: Stainless steel; Reversing mill.

MELHORIA NA QUALIDADE E PRODUTIVIDADE NO PROCESSO DE LAMINAÇÃO DE TIRAS A FRIO DE AÇO INOXIDAVEL

Resumo
Recentes e próximas evoluções em laminação a frio são apresentadas com as suas influências em várias opções viáveis de rotas de processo, no arranjo das oficinas de laminação do início deste século. Para melhor conhecimento das vantagens econômicas como redução de inventário, diminuição do tempo de pedido-envio, e melhoria na produtividade, a integração da laminação a frio com as linhas de recozimento e decapagem traz para alguns novos tipos de aço vantagens definitivas. Em paralelo, o laminador reversível se torna o complemento ideal, com uma forte demanda de mercado pela sua facilidade por deixar o processo mais flexível.
Palavras-Chave: Aço inoxidável; Laminador reversível.

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1 INTRODUCTION

We shall focus in the present paper on cold rolling evolutions and their influence on overall process route available options, in the arrangement of a cold mill at the beginning of this century. Pickling and annealing technology will be addressed in a following paper. We are having a special mention for welders, a key component having a determining influence on the yield, both in thickness and surface aspects, particularly its “rollability”, and its impact on line rolls.

2 INTEGRATED LINE CONCEPT: ADVANTAGES AND LIMITATIONS

The integration debate is about cold rolling, since the main reduction tool in this industry has been the reversing mill: the 20-high mill, sometimes complemented by a Z-high mill. The issue is, therefore, first to design a tandem mill doing the work, and then to include it into either a hot-rolling annealing and pickling line (HAPL) or a cold-rolling APL (CAPL). Skin-pass mill integration into CAPLs has become common, as, for example, recently implemented by Siemens VAI MT in the latest POSCO APF line in Pohang.
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.

Figure 1: Isbergues LC2i - tandem mill area.

Some recently introduced stainless steel grades seem to derive specific process advantage 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” mill principle originally invented by T. Sendzimir, a special 6-high mill with driven intermediary rolls and small – approx. 140 mm diameter – work rolls, equipped with side support roll assemblies on front and back side of work rolls.
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-high reversing mills: for most lines from 25% up to 60%, with a technology limit near 70%, 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.

Figure 2:

3 ENVIRONMENT, HEALTH AND SAFETY

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:

- RCM 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 the paper and the banding strips used for the coils between RCM and downstream process

Infrastructure is also reduced, per ton prodiced, 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

4 COLD MILL TECHNOLOGY NEAR FUTURE FOR STAINLESS STEEL: IN-LINE OR REVERSING, 20-HIGH, Z-HIGH, AND “POWER X-HIGH” TECHNOLOGIES

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.

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, 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.

In most cold rolling plants for stainless steel, 20-high mills do the entire cold reduction work, while some have introduced a reversing Z-high in complement.

4.1The 20-High Reversing Mill

Perfectly adapted to cold rolling hard material down to thickness less than 0.2 mm, the 20-high mechanical technology, however, has only marginally evolved since its introduction in the 1950's. Innovations concentrated on flatness actuators improving control but also increasing complexity, housing design such as the "split housing concept", and ancillary functions such as oil wiping devices or roll change. Siemens VAI MT has recently introduced the SI-Flat, a non-contact flatness sensor that meets with strong success 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-high evolutions?

- The fixed small work roll diameter limits reduction rates on first passes, especially for thick incoming material
- Flatness actuators and mechanical arrangement still need costly attention and skills
- Speed – and thus productivity – is limited due to cooling efficiency constraints
- The use of mineral oil is costly in itself
- Its inadequacy for continuous rolling in an integrated line

4.2The Z-High Mill

Adapted to rolling the middle part of the thickness range, this mill has work rolls larger than 20-high mill rolls and is also suitable for black strip rolling, as pioneered at NYBY in Sweden, as well as for in-line rolling in both hot and cold APLs.

4.3The Power X-High Mill

The power X-High concept being developed by Siemens VAI MT will accept different roll diameters to optimize the average reduction rate per pass. Strip and roll cooling will also be improved, to push further the thermal barrier still limiting speed and reduction.
In turn, it will improve mill productivity at a reduced operating cost, while consuming less electricity per ton rolled. This mill will be available both in tandem configuration, for in-line rolling, or as the main component of a new or revamped reversing mill.

4.4 Cold-Rolling Lubricant and Coolant

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, seem promising: their application range may increase for stainless steel cold rolling when their stability and operating temperature widens. Siemens also benefits from the efficient range of its in-house Schneider filters fit for numerous mill coolant applications.

4.5 Si-Flat Non-Contact Flatness Sensors

For most surface-sensitive steel products, each roll is a potential source of defects to be carefully monitored. Siemens' SI-Flat sensor, separately described, 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.

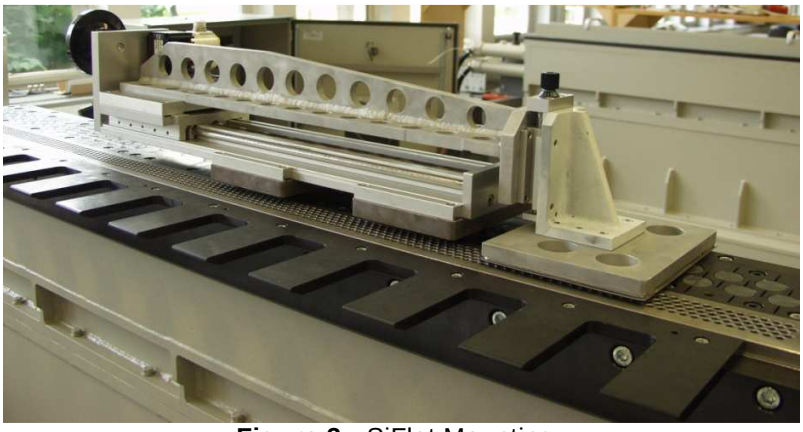


Figure 3: SiFlat Mounting.

4.6 Test Cold Rolling Mill

Siemens VAI MT in Montbrison, France, maintains in its workshop a narrow-band test cold mill in operation, fully instrumented and recently upgraded with the latest AGC and automation. 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.

Figure 4: Narrow band test mill.

4.7 A New Generation Of Laser Welders

CLECIM® laser welders developed by Siemens VAI MT have just recently been designed from a blank sheet, taking into account the existing market experience in this field. The light-gauge laser 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.
The heavy-gauge laser welder still has a mechanical shear, but considering the importance of cut preparation, our engineers built the whole machine around this shear, with extremely reliable cutting pattern reproducibility. Seven light and heavy laser welders have been already delivered in total.

Figure 5: Laser Welder.

4.8 Automatic Surface Inspection

SIAS® automatic surface inspection devices by Siemens VAI MT, with their 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.

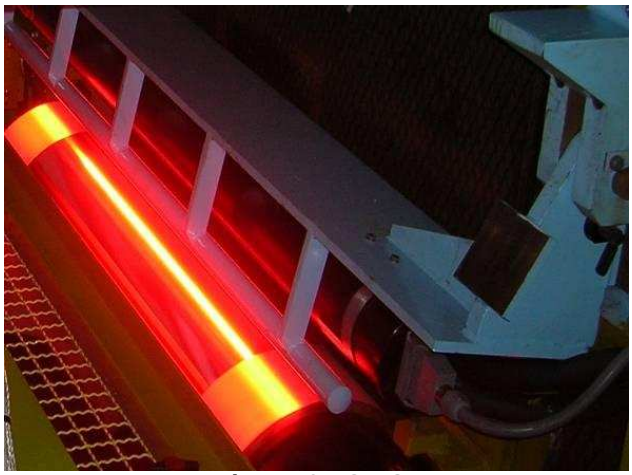
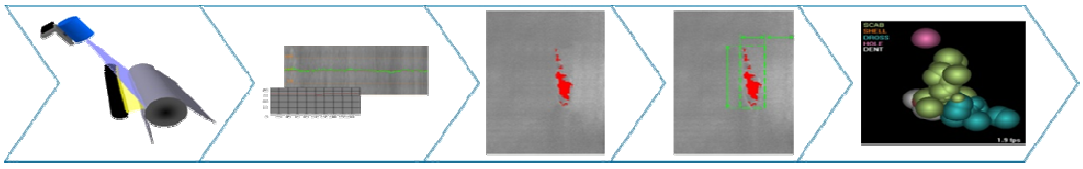


Figure 6: SIAS.

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.



5 CONCLUSION

Siemens VAI MT plays a significant role in the continuous in-line rolling of stainless steel, with the mechanical supply of the UGINE LC2i in Isbergues, France, started in 1999, of the automation of the RAP5 of Outokumpu in Tornio, Finland, and the mechanicals of the DRAP line recently installed at LISCO in Guangzhou, China.

Siemens VAI has 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. Mechanical and automation revamps and technology services are also available through Siemens' worldwide network for specialized support.