MOST ADVANCED COLD ROLLING REVERSING MILLS FOR ECONOMICAL PRODUCTION AND HIGH STRIP QUALITY [1]

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Abstract
Cost effective production of high quality cold strip requires tailor made mill concepts with most modern technologies to face the worldwide competition and new developments in steel grades and qualities. Reversing cold rolling mills in particular are requested to feature highest flexibility. Moreover modern cold rolling mills shall also be designed future oriented to fulfill tomorrow's quality and output requirements. SMS Demag developed advanced reversing mill concept as well as technology tools to grant their customers a leading position by optimization of production costs, yield and strip quality.
Key words: Advanced developments for economical production

TECNOLOGIA DE PONTA EM LAMINADORES REVERSÍVEIS PARA PRODUÇÃO ECONÔMICA DE TIRAS A FRIO COM QUALIDADE SUPERIOR

Resumo
A produção de tiras a frio a baixo custo requer conceitos de laminadores feitos sob medida com a mais moderna tecnologia disponível para enfrentar a competição mundial e o desenvolvimento de novas classes e qualidades de aços. Laminadores à frio e reversíveis são necessários, em particular, para atingir grande flexibilidade.
Além disto, modernos laminadores a frio precisam ser projetados para os dias de amanha para fazer jus aos requerimentos de qualidade e acabamento futuros.
A SMS Demag desenvolveu conceitos bem como ferramentas tecnológicas para permitir aos seus clientes uma posição de vanguarda otimizando os custos de produção, o rendimento e qualidade das tiras.
Palavras-chave: Desenvolvimento avançado p/ produção econômica.

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In former times steel producers had to decide between a flexible single-stand reversing mill with a yield of only 350,000 - 450,000 t/y and a multi-stand tandem mill that can only operate economically for large quantities of over 900,000 t/y.
Initiated by the development of the CSP thin slab casting technology for the production of approx. 1 Mio. tons of hot strip in mini-mills SMS Demag developed a cold-rolling mill concept matching the production of the CSP technology: the *CCM Compact Cold Mill*.
This two-stand reversing cold rolling mill meets the requirement for economical production of high-quality cold-rolled strip of up to 0.9 million tons per year and thus closes a gap in the cost-optimized production of cold-rolled products between single-stand reversing mills and large tandem mills.

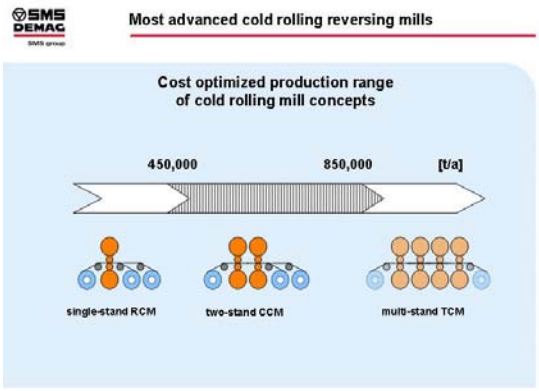

Figure 1.Cost optimized production range of cold rolling mill concepts

Today SMS Demag can offer the tailor made solution for each scheduled output. Five (5) orders for 2-stand reversing mills and a continuous worldwide interest in this technology prove the importance of this new cold rolling mill concept.

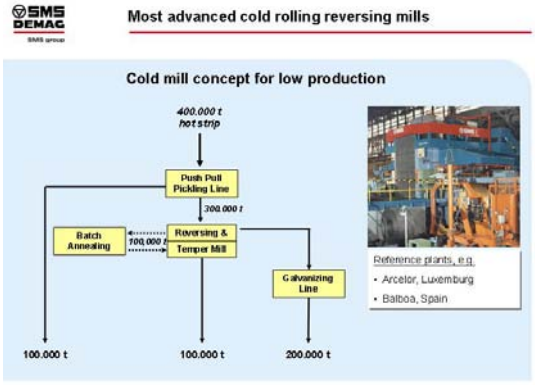

Figure 2. Cold mill concept for low production

Low and medium quantities of hot strip are typically pickled in low cost push pull pickling lines, processing coils one by one. After cold rolling the hardened strip needs to be annealed above re-crystallization temperature before being tempered.
Individual rolling and temper mills are far below their production capabilities and thus would work uneconomically. A combination of both processes within one mill by processing coils lot-wise either in reduction mode or in temper mode reduces investment and operation costs. The switch-over from one mode to the other can be realized with-in a few hours.

A combined reversing/temper mill is most cost effective for low quantities. According to our experience customers with low capacity plants or newcomers in the cold-rolling business prefer this solution.

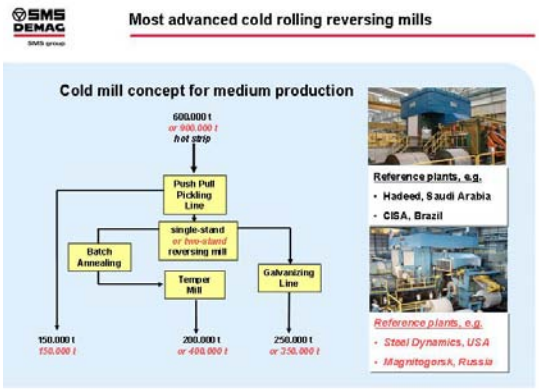

Figure 3. Cold mill concept for medium production

When exceeding a production of approx. 350.000 tons per year a single-stand reversing mill normally does not have additional capacity to temper this amount of cold rolled coils. Consequently a separate temper mill is required. A two-stand reversing mill is able to process even higher outputs. Depending on the product mix up to 0.9 Mio tons of steel can be cold rolled. This output can typically be processed in a downstream single-stand temper mill.

Figure 4. Features of the CCM Compact Cold Mill

The CCM mill configuration with pay-off station and two finishing reversing reels offers high flexibility through multiple rolling strategies. Depending on the material grade and the required total reduction, single-pass, two-pass and three-pass strategies are possible.
Typically a two-pass strategy with four reductions is applied for low-carbon and high-strength low-alloy steel grades. The performance is comparable with a 4-stand tandem mill. If only light reductions are required as in the case of thin hot strip, a time and cost-saving single-pass strategy may be applied with only two reductions. Even six reductions are possible for rolling ultra-light gauges or high-strength grades with silicon content or stainless steel.
The CCM flexibility does not only refer to the number of rolling passes. Various possible mill stand configurations ensure tailor-made solutions for quality and product mix requirements.

These are 4-high mills or using even 6-high mill configuration for highest demands offering the additional advantages of intermediate roll bending and shifting as well as edge drop control.
Originally the CCM concept was elaborated for a typical mini-mill. But thanks to its high flexibility, the CCM was also recognized as being the tailor-made concept for the production of special products in integrated steel plants.

Figure 5. The superiority of the CCM concept

A comparison of investment and production costs for alternate mill concepts based on an annual output of 0.8 million tons proves the economical superiority of the CCM concept.
The investment costs for, necessarily, two individual single-stand reversing mills are remarkably higher compared to the CCM. Not only mechanical and electrical equipment but also civil construction like foundation works and bay sizes can be cut by more than 40 % when deciding for the CCM concept.
The total operation and maintenance costs, especially labor costs, for running one Compact Cold Mill instead of two individual small mills are about 50 % lower. This substantial operation cost saving will be effective year by year.

Figure 6. The CCM is quick on profit

The economical advantages of the CCM concept compared to two single-stand reversing mills for a targeted output of approx. 0.8 Mio. t per year result in a shorter payback time of the investment costs since the CCM is quick on profit.

Figure 7. CCM Jinan

One of our latest references, the CCM mill of Jinan, China, showed the big advantage of receiving the whole equipment from one source.
Workshop assembling of major components, extensive integration tests of the automation systems and a competent commissioning staff ensured a very fast start up of the mill from the 1st Coil, produced in December 2005, until the final acceptance in March 2006 within only 3 months.

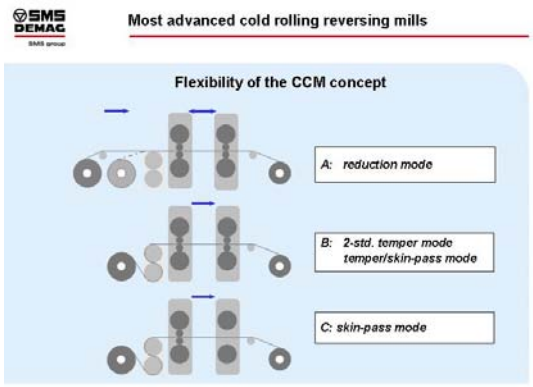

Figure 8. Flexibility of the CCM concept

Also the two-stand reversing mill can easily be extended to be operated as a combination mill for reduction mode and temper or skin-pass mode.
Especially thin gauge strip is preferably tempered with two mill stands to make use of a high interstand strip tension. For example tinplate with final gauges below 0.25 mm is typically processed in double stand mills. The temper elongation is performed by the first mill stand while the second mill stand transfers desired roughness to the strip surface.
Another known application is to perform a second rolling pass after annealing with high strip elongation in the range of 10 %.
In case only a single stand skin pass is required, one set of work rolls can be dismantled and the CCM can be operated as a conventional single-stand skin-pass mill.

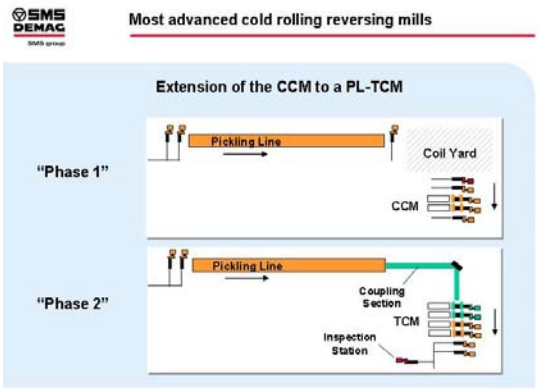

Figure 9. Extension of the CCM to a PL-TCM

In order to maintain flexibility for future increase in production, the 2-stand mill could be supplemented by additional mill stands and linked to a pickling line thus creating a fully continuous PL-TCM.
In a first phase a separate pickling line and CCM are arranged with an intermediate coil storage yard. For the extension of phase 2 the pickling line - depending on the desired output - may be upgraded with an additional pickling tank. The CCM should be completed by 2 or 3 more mill stands to a full-size tandem mill. Space for the foundation should preferably be provided before.
Finally a coupling section with looper - whether like illustrated in 90° diverting or in straight arrangement - links the pickling line with the tandem mill to feature a fully continuous PL-TCM.

Figure 10. Cold rolling reversing mills for special steel grades

In 2001 the China Steel Corporation (CSC) in Kaohsiung, Taiwan, invested in a CVC 6-HS reversing mill with the objective to enhance the existing capacity for cold-rolled steel by special steel grades and smaller final thicknesses.
For attaining the high quality requirements especially with regard to thickness and flatness, the mill stand is equipped with hydraulic roll gap setting, intermediate roll axial shifting with CVC plus technology, work roll and intermediate roll bending systems and multizone cooling system. The work roll horizontal shifting system enables setting of the optimal horizontal forces in the roll assembly. For strip edge control, in particular for silicon steels, the work roll axial shifting system is installed.
Beside the mechanical equipment and media systems, the SMS Demag scope also included all technological controls and physical process models for precise presetting of all technological actuators. Thus SMS Demag supplied a complete technology concept for the cold rolling of special steel grades.

With the aid of the highly dynamic setting systems and the technological controls, even the narrow tolerances for the strip thickness and flatness were achieved and surpassed . This CVC 6-HS reversing mill achieves highest quality requirements and is able to come up to future market requirements on the currently rolled products and new ones.

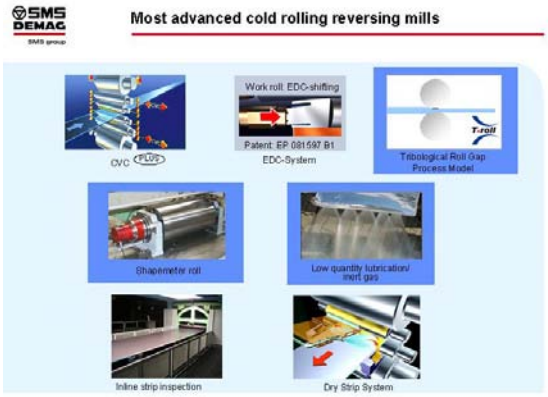

Figure 11. Technology packages and system supply

In order to follow the market as well as the customer requirements to improve the strip quality we have developed different technology packages and technical solutions. Some examples are shown in the picture:

- CVC Plus (Continuously Variable Crown)
- EDC (Edge Drop Control)
- T-Roll (Tribological roll model)
- Shapemeter roll with flatness control
- Inert gas cooling with minimized oil lubrication
- Inline inspection
- DS System (Dry Strip System)

T-Roll model, flatness roll and inert gas cooling will be explained in more detail.

Figure 12. T-roll opens new possibilities

An increasingly important precondition for plant optimization is the exact knowledge of the rolling process and specially the physics in the roll gap.
For this reason T-roll was developed in close cooperation with our customers. This technology package considers mechanical, thermal and tribological aspects of the rolling process in a new, physically based approach. It opens completely new

possibilities for process design, product quality improvement and an increase of plant productivity.
According to customer requirements this technology package needs to be developed for several possible applications. The service tool for the off-line analysis and calculation of set-up data is available in the SMS Demag office. Sub-sequent improvements of the rolling process as well as an accurate pre-calculation for new products help to optimize existing plants. SMS Demag uses the T-roll technology also for layout and design of new mills.
The online application of T-roll provides the possibility of implementation as a module into the level 2 control system for a continuous improvement of product quality and higher yield. An additional add-on monitoring tool analyses and evaluates the rolling process conditions, specially the lubrication conditions.

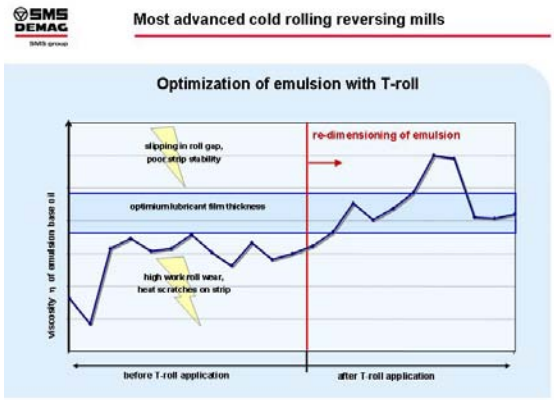

Figure 13. Optimization of emulsion with T-roll

As an example a reversing cold-rolling mill for grain-oriented silicon steel of Thyssen Krupp Electrical Steel was optimized using T-roll. As one result parameters of the emulsion base oil have been re-dimensioned.
Before the optimization low viscosity created too high friction and produced heat scratches on the strip surface in combination with high roll wear. Too high viscosity resulted in slipping and instability of the roll bite.
Finally the optimized viscosity could be calculated and adjusted after the application of the T-roll technology.

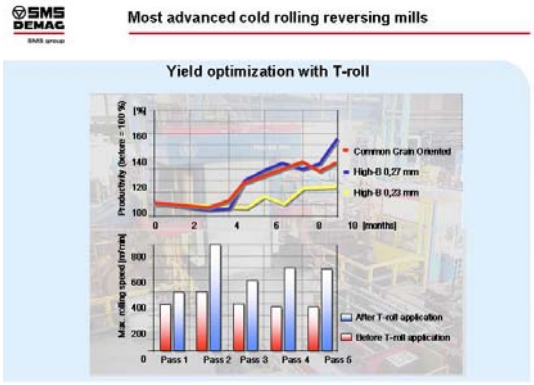

Figure 14. Yield optimization with T-roll

A significant increase of productivity due to optimization of pass schedules and rolling speeds could be achieved as result of this optimization.

The top diagram shows the increase of productivity of this reversing mill due to optimization of pass schedules and lubricant properties. The bottom chart reflects the improvement of a representative pass schedule. The rolling speed of each reversing pass has been increased.
In addition to these effects off-gauge lengths as well as the number of strip breaks have been reduced.

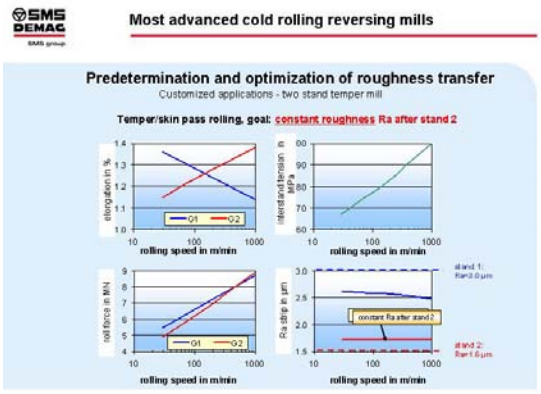

Figure 15. Predetermination and optimization of roughness transfer

Another possible application of T-roll is shown here by means of temper/skin pass processes. The constant transfer of roughness to the strip while maintaining a desired constant strip elongation is the major target of two-stand temper/skin pass mill .
The T-roll model pre-determines the influence of an increasing rolling speed to strip elongation and rolling force for each individual mill stand and supports the operator to select the right set-up and control strategy for the various parameter in order to maintain a constant strip roughness and constant elongation after the last pass under varying rolling conditions.

Figure 16. Solid shapemeter roll for optimized flatness control

With the market demand to receive reliable measuring data for the online flatness control we found a suitable solution ot comply with this request: Manufacturing of the flatness roll on BFI license and common testing of the unit with our automation system in our own workshop.
The new design of the roll offers the following advantages:

- Easy sensor installation
- Installation also possible at our customer's facility

- Individual arrangement of sensors
- Closed roll surface
- Unproblematic roll coating using a large variety of materials
- No air connection required

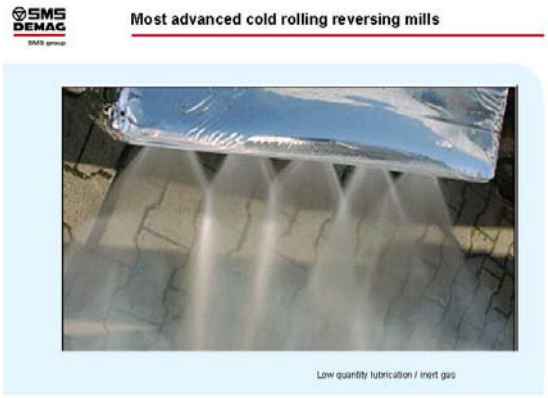

Figure 17. Low quantity oil lubrication and inert gas cooling

A further development is the low quantity lubrication with inert gas cooling. Trails for more than 2 years now showed the big advantage for optimized strip surface quality and less roll wear – thus reducing the production costs by approx. 25 % (based on the experience at Wälzholz). Even though this new development is still in the starting phase as regards implementation into further production lines, we expect to get this system transmitted also into the last stand of Tandem Mill in the near future. Necessary trials are already under progress.