Advanced technology in skin pass rolling

The increased requirements demanded of cold-rolled strip in terms of mechanical properties and surface quality have meant that skin pass rolling, as the last step in the process chain, has become more important. New developments in control of flatness and surface quality, together with increased plant flexibility to handle a diverse range of products are described.

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Against the background of a global market, rolling-mill owners are under constant pressure to cut their production costs and to open up new market segments with the help of innovative products. At the same time, requirements in terms of strip quality, such as thickness and flatness tolerances, surface structure and mechanical properties, are becoming increasingly strict.

SMS Siemag, as a provider of complete solutions for rolling mill equipment, is faced with the challenge of taking appropriate measures to help achieve these targets. Therefore, conducting continuous and wide-ranging development activities is indispensable to SMS Siemag. Long-standing solutions need to be questioned and new technologies examined for their usability and benefits in rolling mills.

With regard to skin pass rolling, our main areas of development are:
- Improving flatness and surface quality
- Increasing flexibility to handle high-strength material such as DP1000 as well as very soft material like interstitial-free (IF) grades
- Improving the automation by process models and control systems based on innovative online measurement devices

USE OF LOW VOLUME LUBRICATION AND LIQUID NITROGEN
SMS Siemag has developed, together with Air Products, REBS and C D Wälzholz, a new lubrication and cleaning concept involving a combination of low-volume lubrication and the utilisation of liquid nitrogen in skin pass rolling. This concept significantly improves the strip surfaces and minimises operating costs.

The low-volume lubrication system applies the lubricant in the skin-pass stand entry. This reduces the friction in the roll gap and hence the roll force, and improves flatness while using a minimum amount of lubricant. The liquid nitrogen in the exit covers both the strip and the roll surfaces (see Figure 1).
This method has the following advantages:

- Clean and dry strip surfaces and thus lower susceptibility to rust
- Clearly reduced efforts in the downstream steps for cleaning the strip surface
- Extended work roll service lives

**Low-volume lubrication** Considering the fundamentals of lubrication according to Stribeck (see Figure 2), cold rolling takes place in the area of boundary lubrication. This means the roll and strip come into occasional contact.

Surplus lubrication with higher speed causes more lubricant to be drawn into the roll gap, hence roll and strip are better separated by lubricant pockets, but this causes imprints of the lubricant on the strip surface.

With low-volume lubrication, which applies around 0.3–0.4ml/m, only a film is produced, which is thinner than the combined roughness of the strip surface and roll, and so these imprints are avoided.

The major components of the low-volume lubrication system are very compact and comprise the nozzle beam, a volume controller and the tank, pump and control unit. Two nozzle beams are installed: one for the top and one for the bottom strip surface. Due to the small amount of lubricant, its equal distribution can only be ensured by atomising it with compressed air. The volume controller ensures a constant flow rate during operation. Three configurations are available: one controller for each nozzle, one for a group of nozzles and one for a single nozzle beam.

Figure 3 shows the assessment of the strip surface quality rolled with and without low-volume lubrication. In both cases the same material was rolled. The typical imprints of the lubricant cannot be observed and the strip surface quality is fully comparable.

In addition, low-volume lubrication means that roll force is reduced as even a very small amount of oil causes a remarkable decrease in roll force (see Figure 4). By varying the amount of oil over a considerable range the roll force can be adjusted. This opens up new options in controlling skin pass rolling.

**Liquid nitrogen** Typical installation consists of vaporiser and nitrogen tank, which are installed outside the mill building. The tank is connected to the nozzle system via a vacuum jacketed line and supply is controlled via valves (see Figure 5).

To assess the strip surface quality using liquid nitrogen, the same material was skin-passed under different operating conditions (see Figure 6). In the pass with emulsion (left), clear impressions of the lubricant were found. They make the surfaces appear less bright. The roll abrasion in dry skin pass rolling has a similar effect.
on the surface quality (middle). In comparison, surfaces are clearly more uniform and thus brighter when using liquid nitrogen (right).

Moreover, operating experience has shown that the use of nitrogen more than doubled work roll service lives. This, and the lower refinishing effort on the strips, enabled our co-operation partner C D Wälzholz to cut process costs of skin pass rolling by approximately 20%.

To prove this, five strips were skin passed in the dry condition and 10 with liquid nitrogen on the exit side (see Figure 7). All strips were equal in quality and dimensions. At the end of every coil, work roll roughness was measured. After only four coils rolled in dry conditions, roughness dropped below the demanded value of Ra =1.0µm, and in normal production a work roll change would be necessary. When liquid nitrogen was applied on the exit side, the roughness of the work roll was maintained for considerably longer. Even after 10 coils the roughness did not drop below the required value.

This results from the cleaning effects of liquid nitrogen which can be explained by thermal shock. In this context the thermal shock describes the sudden cooling of the roll surface by liquid nitrogen. Due to the different thermal expansions of the roll surface and accumulations of abrasive material and dirt glued together by residual oil, as well as the difference in thermal conductivity, the accumulations in the roughness valleys become brittle and flake off. This cleans the rolls and, in a similar way, also the strip surface.

**Low-volume lubrication and liquid nitrogen at ThyssenKrupp Steel** A combination of low-volume lubrication and liquid nitrogen application has been installed in the new inline skin pass mill at the continuous annealing line of ThyssenKrupp Steel in Dortmund. It produces a large spectrum of steel grades, from soft IF steels up to high-strength transformation induced plasticity (TRIP) grades (see Figure 8). The skin pass stand is equipped with deflector and anti-crimping rolls in both the entry and exit sides. The oil is applied before the defector roll at the entry side and liquid nitrogen is applied at the exit side covering only the roll surface, which does not reduce system benefits.

**EXTENDED BENDING SYSTEM** With a wide product mix, a skin pass mill has to meet many requirements. For ultra-soft material like IF steels with a very low strip elongation of 0.5%, very low roll forces must be used. High-strength strip requires greater elongation, corresponding to high roll forces.

The mill stand must be designed to suit the maximum roll force so adjusting for low roll forces becomes more
difficult. For ultra-soft material, measures like increasing the work roll diameter, reducing roll load and the amount of emulsion used will not be enough to keep the roll force controllable. SMS Siemag has thus developed the Extended Bending System (see Figure 9) for very low roll forces of 10% or less of the maximum roll force. Here, the roll force (<700kN) would be below the dead weight of the back-up roll. With the extended bending system the top backup roll is lifted up in the stand by collapsing the hydraulic gap control cylinders and the roll force is applied only through the roll bending system of the work roll or intermediate roll. This is sufficient to apply the required roll force in a controllable range and the required low strip elongation.

The latest reference plant for this system is the CVC® plus 6-high inline skin pass mill at the continuous annealing line at Baosteel, China.

T-ROLL®
To optimise the cold rolling process in general, and skin pass rolling in particular, it is essential to better understand the physical processes taking place during rolling. SMS Siemag has developed T-Roll®, a technological offline model with a special focus on the tribological processes taking place in the roll gap. Besides dimensioning of cold rolling mills and analysing rolling processes on the site, the T-Roll® modules become part of the online process models or the technological control system.

The feed-forward module of the elongation controller is an example of this (see Figure 10) and provides for more dynamic elongation controllers, so keeping elongation and flatness within close tolerances, especially during acceleration and deceleration.

Basically, the elongation is adjusted by the control variables of roll force and entry as well as exit strip tension. The strip tensions can only be used if the plant is equipped with bridle roll units in the entry and exit for decoupling the reel tensions from the elongation tensions.

Besides the feed-forward module the structure of the controller consists of a tension control component as well as an adaptive force control component for feedback control. The feed-forward module calculates, based on the implemented model, the actual set-up as well as the actual speed, the force and tension values, which are added to the output of the feedback controller. Thus, the elongation control achieves the desired elongation faster in transient situations and so reduces the length out of tolerance.

The difference in the adjusted force by the feedback control and the predicted force by the feed-forward module is shown in Figure 11. It is apparent that the feed-forward controller would raise the force faster and thus reduce the off-tolerance length.
When both controllers are active this reduces the variation of the elongation even under the test condition as demonstrated in Figure 12.

**ONLINE MEASUREMENT SYSTEMS AND PROCESS AUTOMATION**

Today, efficient production at high levels requires complete documentation of the main quality parameters. This is the only way to demonstrate quality to the customer, to track down causes of problems in the process line efficiently and to improve process control. Our patented roughness control system maintains the strip roughness to a constant value along the entire length and enables rolls to be changed only when necessary.

With low-volume lubrication the friction coefficient can be adjusted in the complete range from dry to wet skin pass rolling and so opens up a wide operation window to adjust the roll force. Besides the elongation, the strip roughness can be controlled to a constant value considering the degree of wear of the work roll.

For roughness measurement, the SORM 3 plus measuring system of our co-operation partner EMG is used. Together with our partner SYSTECTUM, SMS Siemag has developed an online measurement device to detect the residual oil contents (see Figure 13). The system works on the laser-induced fluorescence principle.

For flatness measurement, SMS Siemag offers a shape meter roll based on the BFI approach. The close surface of the roll avoids marking of the strip and can be specifically coated for every application. The roll allows simple installation of the sensors, which can be performed at the side. The overall functionality of the advanced automation system for a skin pass mill is shown in Figure 14.

**CONCLUSIONS**

When considering the higher requirements in terms of mechanical properties and surface quality of cold-rolled strips, skin pass rolling, as the last step in the process chain, becomes more important. The innovative technologies from SMS Siemag help to reduce operating costs, increase plant flexibility and improve strip quality. *MS*

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