CONSIDERATIONS FOR APPLYING ROLL GAP LUBRICATION, WORK ROLL COOLING AND ANTI-PEELING SYSTEMS IN HOT ROLLING MILLS

Michael J. Peretic[1]
Juergen Seidel[2]
Stephan Kraemer[3]

Surface quality requirements for hot rolled steel sheet have continued to become more stringent in recent years. This sheet quality focus has developed in parallel with corresponding demands for increased productivity and reduced costs at the mill.

Although not a panacea, roll gap lubrication systems have been receiving increased attention in support of these objectives. Specifically, roll gap lubrication systems are used in combination with work roll cooling systems and anti-peeling systems to:

- Reduce rolling loads and thereby reduce potential for chatter
- Reduce rolling torques, and associated energy requirements
- Reduce potential for rolled in scale by reducing work roll peeling
- Extend work roll campaign length by reducing peeling (and potentially wear)

This paper will discuss how roll gap lubrication, work roll cooling, and anti-peeling systems can be utilized in a coordinated manner to reduce the potential for chatter and peeling, thus enhancing strip surface quality, improving mill productivity, and reducing operating costs.

Keywords: roll gap lubrication, work roll cooling, anti-peeling

41st ABM Rolling Seminar, Processes, Rolled and Coated Products,
October 26-28, 2004, Joinville (SC) – Brazil

---

[1] Principal Engineer – Process Technology - SMS Demag Inc. – Pittsburgh, PA, USA
[2] Deputy General Manager – Hot Rolling - SMS Demag AG – Hilchenbach, Germany
[3] Manager – Hot and Cold Rolling Technology - SMS Demag AG – Hilchenbach, Germany

1. Introduction

Mill chatter and work roll peeling can occur in the stands of hot finishing mills when rolling with high roll surface temperatures, high loads, and/or high reductions. These conditions can damage the work roll surface, and adversely affect strip surface quality.

The effective implementation of roll gap lubrication, work roll cooling and anti-peeling systems can provide enhanced control over the thermal and tribological conditions in the roll bite to achieve objectives for enhanced product quality and mill productivity.

2. Overview - Chatter and Peeling on Roll Surfaces

The early stands of steel hot finishing mills routinely operate at relatively high loads and relatively low speeds. These operating conditions represent a very aggressive environment for mill work rolls.

High loads, combined with other factors, can contribute to mill stand vibrations commonly known as chatter. These vibrations produce cyclic loading conditions in the stand, which can produce visible marks on the roll surface as shown in Figure 1. These marks are then transferred to the sheet, producing an undesirable surface quality.

The effective implementation of roll gap lubrication technology can make it possible to reduce and / or redistribute loads in the mill, thus decreasing or eliminating chatter.

Figure 1: Chatter

Furthermore, the strip surface temperature, and the contact time between the strip and the work roll, impacts the temperatures that are reached on the roll surface. Higher temperatures accelerate the formation of oxides on the roll surface, and thin layers of these oxides can then be "peeled off" by the alternating shear stresses associated with slip in the roll bite[1].

When this occurs, it results in a roll surface defect commonly called peeling as shown in Figure 2. These loose oxides are then rolled into the strip surface and are typically called rolled-in scale. Solutions to the peeling problem involve establishing a balance between oxide growth and wear at a minimal thickness in the roll bite[2].

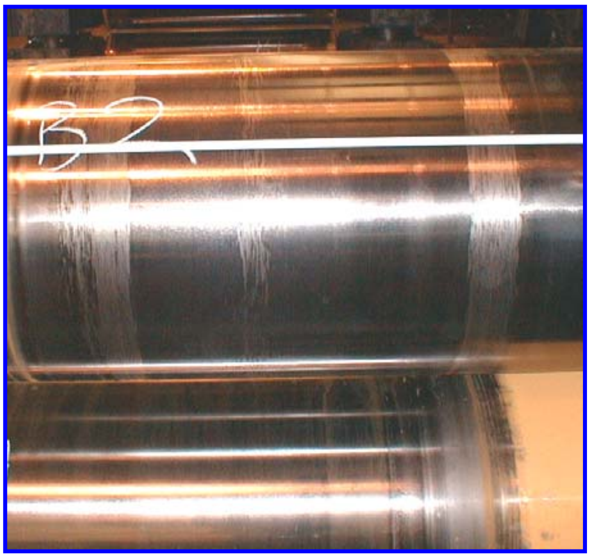

Figure 2: Work Roll Peeling

3. Overview of System Hardware and Operating Philosophy

Figure 3 shows an example of the hardware that provides roll gap lubrication, work roll cooling, and anti-peeling functions in a mill stand.

The work roll cooling headers are installed on both the entry and exit sides of the stand. The area of spray coverage on the roll is largest on the exit side. This provides the maximum cooling effect when the roll surface is at its highest temperature – just after it rotates out of contact with the strip.

The work roll cooling headers on the entry side of the stand are disabled when the roll gap lubrication headers are operated, so as not to wash off the oil before it can effectively plate onto the roll surface.

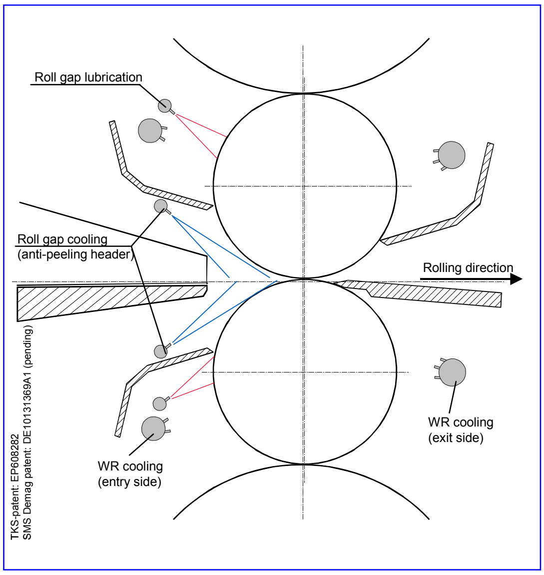

Figure 3: System Hardware

The roll gap lubrication headers are also located on the entry side of the stand. They spray oil/water dispersion onto the roll surface prior to its rotation through the stand entry wiper. As the water component of the dispersion is vaporized, the pressure that is exerted by the wiper enhances the plating of the oil onto the work roll surface. This oil provides lubrication in the bite to reduce loads during rolling.

Anti-peeling headers are also fitted on the entry side of the stand. These headers apply coolant directly onto the strip to reduce its surface temperature before it enters the roll gap. Because of the close proximity to the roll bite, there is very little time for conduction to redistribute the temperature within the body of the strip. Hence, only the strip's surface temperature is significantly reduced before entering the roll bite, while temperatures at the core of the strip remain essentially unchanged. This lower strip surface temperature provides less driving force for conduction to the roll – hence the resulting roll surface temperature is lower. This decreases the rate of formation of oxides on the roll surface, which reduces the tendency for peeling.

4. Roll Gap Lubrication – Oil / Water Supply

A water/oil dispersion is supplied to the roll gap lubrication headers as shown in Figure 4.

Separate systems are provided for top and bottom headers in each stand. The water/oil dispersion is formed in a static mixer located just before the spray header. By creating the dispersion in close proximity to the header, the time for the oil to breakout is minimized.

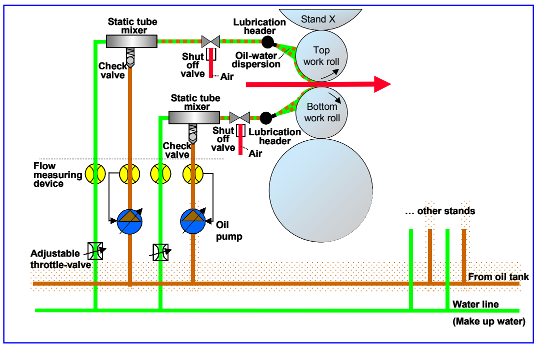

Figure 4: Oil / Water Supply

The oil flow is provided by metering pumps, and is only enabled during rolling. Metering pump speed is regulated to maintain a specified volume flow rate for the process. Adjustable valves regulate the water flow rate which is maintained even when the oil is shut-off to help clear piping deposits and thereby prevent clogging.

Air operated shut-off valves are used to adjust the width of the sprays to cover only the width of the strip being rolled. As a result, the volume of oil consumed is minimized along with the associated operating cost. This is also important for environmental considerations, in that the volume of vapor emissions and the volume of waste fluids that require special disposal are reduced.

It should also be noted that water quality can significantly affect the performance of the oil/water dispersion. Therefore, the oil supplier must work closely with the user to adapt the oil quality to the water quality.

5. Impact of Roll Gap Lubrication and Operating Philosophies

Properly designed roll gap lubrication systems reduce friction in the roll bite, and thereby reduce the resulting rolling load. This effect is seen in Fig. 5, which shows plots of F3 rolling load and roll gap lubrication status (RGL) as functions of time. Although some variations exist, there are predominantly three philosophies that are followed in the operation of roll gap lubrication systems. These three philosophies are shown in Fig. 5(a), 5(b), and 5(c).

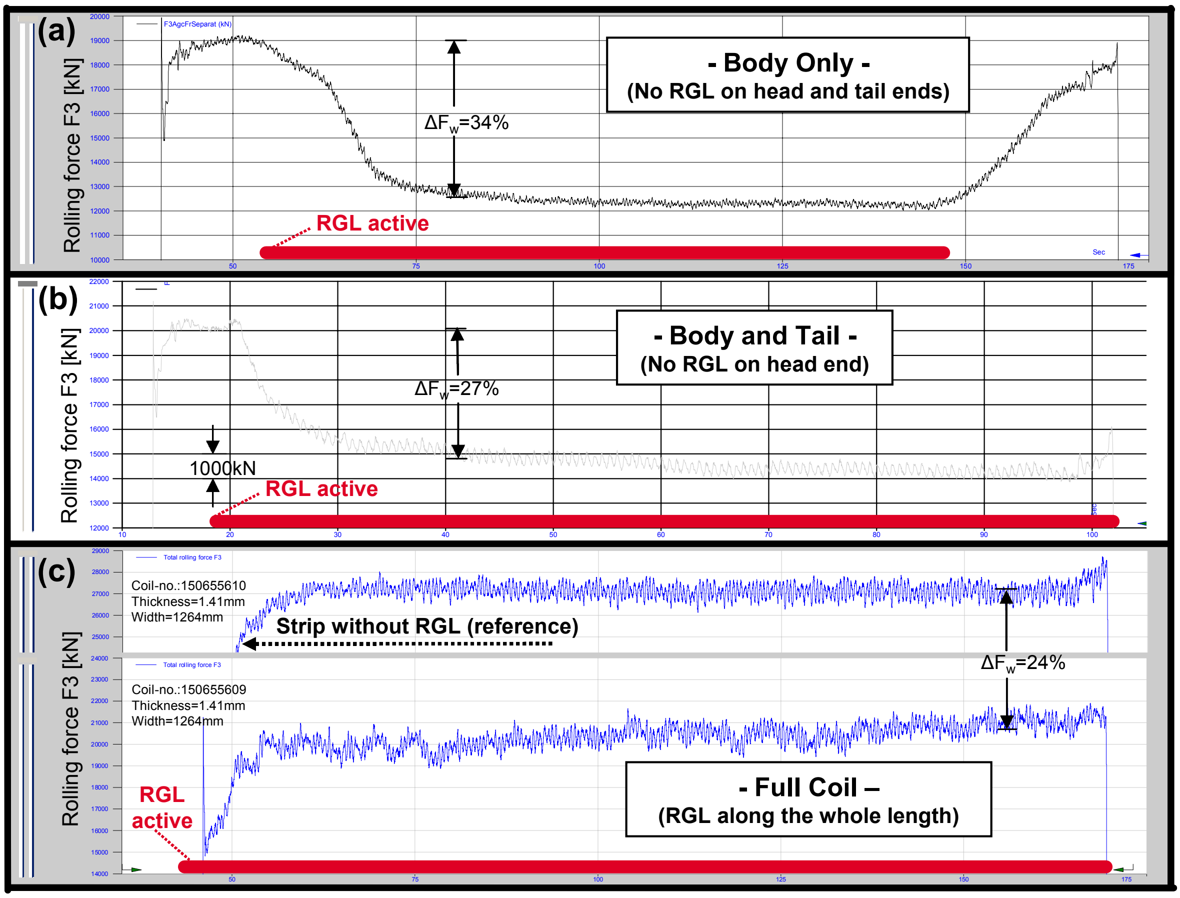

Figure 5: Roll Gap Lubrication Operating Philosophies

Fig. 5(a) represents a “Body Only” philosophy. It is typical of operation for the first stand of the finishing mill, although some roll gap lubrication systems follow this practice on other stands as well. In this philosophy, the oil flow is not enabled until after the strip has threaded through the stand. This provides a higher friction condition during threading to reduce the potential for bite rejection. Note that when roll gap lubrication is enabled, there is a significant reduction in rolling load.

The oil flow is again disabled before tailout, to allow any residual oil that remains on the roll surface to be consumed in the process. This restores the effective friction to a higher level prior to threading of the next strip, and thereby reduces the potential for bite rejection. It also results in a corresponding increase in the rolling load at the end of the coil.

The large changes in load that result from the use of the roll gap lubrication system produce transients that must be addressed by the mill control systems – hence control system upgrades are often required with the addition of these systems.

Fig. 5(b) represents a “Body and Tail” philosophy. This approach has historically been followed on stands F2-F7. Here, the roll gap lubrication system is enabled after threading, but it is not disabled until tailout is completed. This still produces a load transient at the beginning of the coil, but eliminates the one at the end.

This approach may allow some residual oil to remain on the work roll surface for the next threading operation, as it may be only partially washed off by the work roll cooling sprays during their operation between coils. The potential for bite rejection still exists on these stands, but it is much less common due to the operating conditions that exist there.

Fig. 5(c) shows curves for two strips that were rolled with the same exit thickness and reduction. The bottom and top curves represent rolling with and without roll gap lubrication respectively. The ordinate axes from the two graphs are aligned to provide a continuous scale, so that the loading change is quantitatively seen.

The lower curve represents a “Full Coil” operating philosophy as the optimal approach. Here the roll gap lubrication system is enabled shortly before threading and disabled at tailout. This approach provides the loading and strip surface benefits of roll gap lubrication over the entire length of the coil. It also eliminates the loading transients that require response from the mill control systems at head and tail ends. This philosophy can often be applied on F2-F7.

6. Impact of Oil Volume Flow Rate on Rolling Load

The load reduction that is afforded by roll gap lubrication depends upon a number of factors, one of which is the volume flow rate of oil. Nonetheless, there is a point of diminishing returns that is reached when adding more oil.

Representative tests have been performed to analyze the effect of oil flow rate on rolling load at stands F2-F4. Results are shown in Figure 6.

Note that the rolling load reduction on each of the stands appears to be approaching a limiting value asymptotically, as oil volume flow rate is increased. Increasing oil flow rate beyond this point would increase operating cost and environmental issues while providing little or no further reduction in loading.

It should also be recognized that only the upper header was operating on F2 during these tests, hence the more limited reduction in force on this stand.

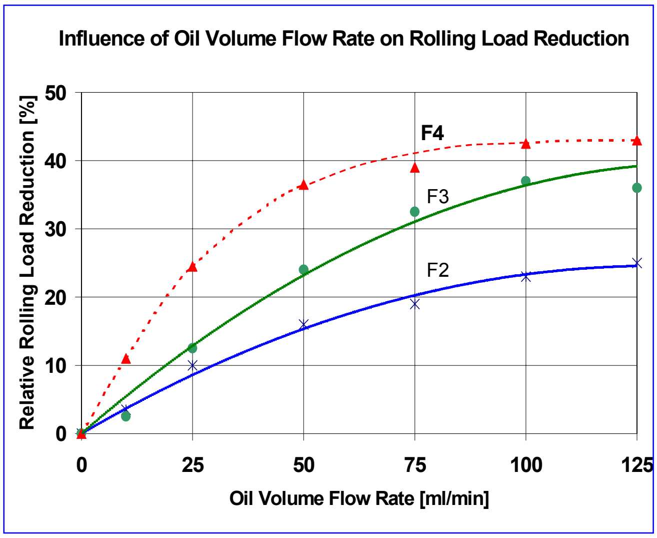

Figure 6: Load Reduction vs. Oil Flow

Other loading and operating conditions, as well as other oil and water dispersions, may exhibit different volume flow rate requirements to approach this limiting point. Nonetheless, the general behavior of receiving diminishing returns for continued increases in oil volume flow rate is expected to hold for these applications as well.

7. Roll Gap Lubrication's Impact on Chatter

Chatter problems are frequently addressed by reducing the load on the stand that is experiencing vibration. This load reduction has historically been accomplished by decreasing the reduction on that stand which requires redistributing reductions across other stands.

Rolling force can also be reduced via application of roll gap lubrication technology. An example of this approach is shown in Figure 7.

The graphs in Fig. 7(a) show the F2 and F3 roll force and associated frequency response spectra for the condition without roll gap lubrication. No significant disturbances are observed in the F2 spectrum, but a significant peak, is observed in the spectrum for F3 at about 42 Hz representing chatter in that stand.

The graphs of Fig. 7(b) show results for the addition of roll gap lubrication with the same exit thickness and operating speed. The reduced load on F3 has eliminated the force disturbance as evidenced in the frequency response spectrum.

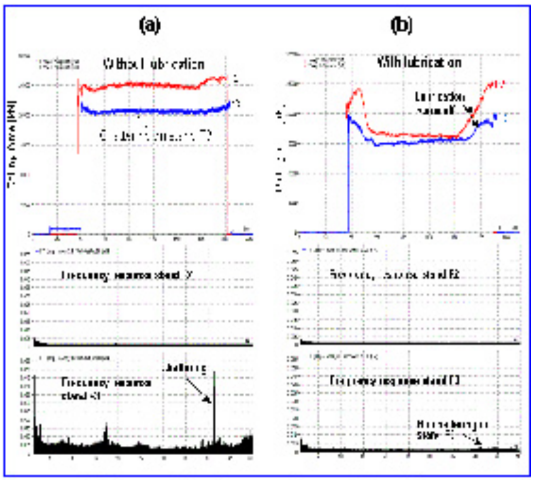

Figure 7: Impact on Chatter

8. Roll Peeling - Analysis of Roll Thermal Loading

The effect of using an anti-peeling header with enhanced work roll cooling was analyzed using a 2-D transient thermal model. The conditions for a conventional mill stand design are represented in Figure 8. The insert at the top left corner of this figure shows the arrangement of cooling headers and boundary conditions for the work roll.

The insert at the top right corner shows the temperature profile through the half-thickness of the strip as it enters and exits the roll bite. Note that the strip temperature profile enters fairly flat at about 965-970°C. As it passes through the bite, the strip surface transfers heat to the roll surface by conduction. This heat transfer lowers the temperature of the strip surface, and raises the temperature of the roll surface. The strip core temperature is higher upon exiting the bite as a result of the heat of deformation generated in the process.

The roll surface temperature varies through each roll revolution as shown in the bottom graph. Region 1 begins as the roll surface exits the roll bite. Here the roll surface is at its maximum temperature of approximately 525°C for these conditions.

As it passes through region 1, the roll surface temperature decreases as heat is conducted away from the surface and toward the core of the roll. The surface also loses heat to the environment by radiation and convection, which further contributes to its temperature decrease.

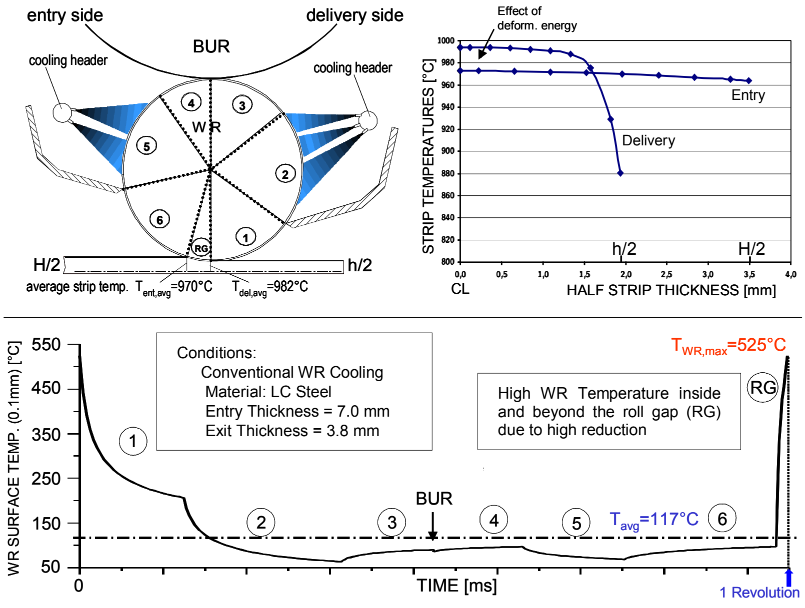

Figure 8: Conventional Stand Design

In region 2, the work roll surface temperature decreases much more rapidly as it is subject to the stronger convective heat transfer from the exit side work roll cooling sprays. At the end of this region, the roll surface temperature has closely approached the fluid temperature of the sprays.

Regions 3 and 4 show some increase in the roll surface temperature due to reverse conduction from the relatively higher temperatures that exist just below the roll's surface. Also, between these regions, a slight decrease in the work roll surface temperature occurs. This decrease occurs at the zone of contact with the back-up roll, where heat is conducted from the work roll to the back-up roll.

Region 5 shows work roll surface cooling from the entry side roll cooling sprays. This is similar to the cooling that occurred in Region 2, but the roll surface temperature is lower, thus the convective effects are reduced. This is followed by surface temperature recovery in Region 6, again resulting from sub-surface conduction.

Finally, as the work roll surface enters the roll bite in region RG, the roll surface temperature is raised again to approximately 525°C from contact with the hot strip. This represents roll surface temperature cycle for rolling conditions.

Cooling from the sprays during “between coil times” would reduce these temperatures. So the maximum roll surface temperatures clearly occur during the rolling cycle when the roll surface exits the bite. Actions must therefore be taken to reduce these temperatures during the rolling cycle.

Roll surface temperature reduction can be achieved via coordinated operation of an anti-peeling header, with the work roll cooling sprays and roll gap lubrication system as shown in the analysis results of Figure 9. Here several of the roll boundary conditions are different as a result of the addition of this hardware. As the upper left insert shows, the entry side work roll cooling sprays are disabled when the roll gap lubrication headers are activated, and since these headers are activated during rolling, two additional measures are taken to provide the required roll cooling.

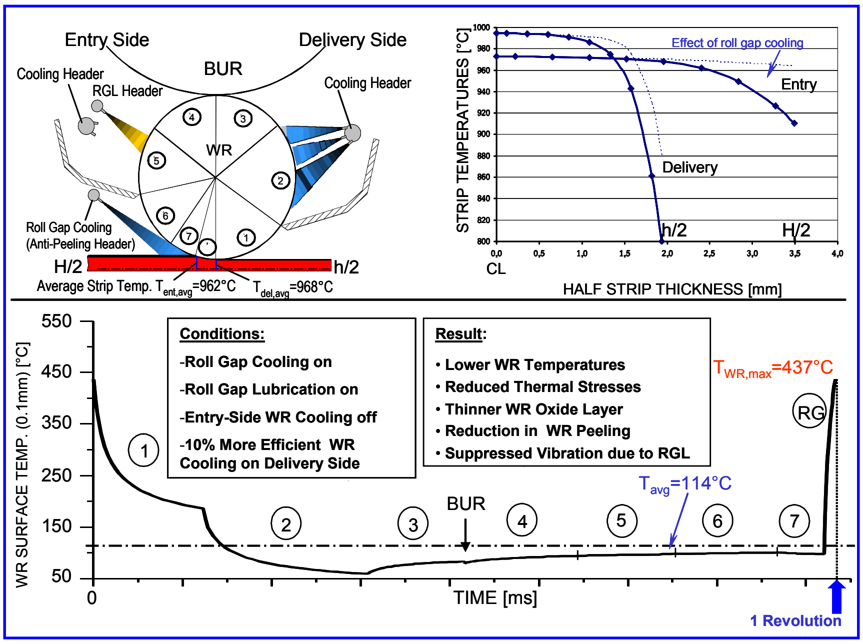

Figure 9: Roll Gap Lube/Work Roll Cooling/Anti-Peeling

First, the heat removal capabilities of the exit work roll cooling sprays have been enhanced by 10%. This provides more convective cooling in the region where roll surface temperature is highest.

Secondly, the anti-peeling header is enabled on the entry side of the stand to reduce strip surface temperature. This temperature reduction is seen in the upper right insert by comparing the dashed curve (without anti-peeling – from Figure 8) to the solid curve (with anti-peeling).

The lower strip surface temperature reduces the driving force for conduction between the strip and the roll. As a result, the maximum roll surface temperature (bottom chart) is reduced to 437°C from the 525°C value that was found for the conventional system in Figure 8. This lower surface temperature reduces the potential for roll peeling while maintaining the benefits of roll gap lubrication.

9. Comments on Other Potential Benefits and Caveats of Roll Gap Lubrication

Reduced roll wear, lower power consumption and other potential benefits are also reported in literature[3,4]. A detailed discussion of these topics is outside the scope of this paper, nonetheless, the following comments are offered for consideration.

It has been suggested that reduced friction from roll gap lubrication decreases abrasion, and therefore provides greater protection for the roll surface[5]. This decrease in abrasion would reduce wear and increase campaign length.

The potential to reduce power consumption during rolling is intuitively obvious. A load reduction provides a corresponding reduction in torque, which translates to corresponding reduction in power when the same operating speed is maintained.

Finally, it is important to recognize, that while these systems may reduce roll peeling and wear, they do not correct for inadequate strip descaling operations. Strip related scale removal should be done with effective entry descaling, and interstand scale suppressing systems.

10. Conclusions

The benefits of the coordinated application of roll gap lubrication, work roll cooling, and anti-peeling systems include having the abilities to:

- Reduce / eliminate chatter by reducing loads
- Reduce loading, torque, and power requirements by reducing friction
- Enhance strip surface quality by reducing potential for work roll peeling
- Increase work roll campaign length by reducing potential for peeling (and wear)

Special considerations should include:

- Rolling oil must be applied in a manner that assures it is carried into the roll bite
- Exit side work roll cooling systems must be enhanced
- Application methodology can be optimized to minimize oil usage and cost
- Inadequate strip descaling from prior operations will not be corrected
- Set-up and on-line control models must be optimized to new rolling conditions

11. References

---

[1] The European Foundry Association; “Roll Failures Manual”, 1st Edition, 2002.

[2] Martiny, Frank, “Some Important Aspects in View of Optimizing Rolling Conditions in Hot Strip Mills when Using High Speed Steel Work Rolls”, Gontermann-Peipers Corporate Publication.

[3] Easey, J. F., John Lysaght (Australia) Limited Corporate Research and Technology, Research and Technology Report No. 540, September 1974.

[4] Arnken, Richard, and Kunkel, Karl, “Practical Application of Hotmill Lubrication in Europe”, Quaker Chemical Report, 1994.

[5] Broekhof, Nico L.J.M., Arnken, R., and Mulder, H., “Maximum Benefits with High-Speed Steel Mill Rolls”, 33 Metal Producing, Nov. /Dec., 2002, pp. 22-24.