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KEEPING SAVINGS TO THE "MAX" – TECHNOLOGIES FOR AN EFFICIENT AND RESOURCE CONSERVING COLD ROLLING PROCESS[1]

Rüdiger Holz[2]
Karl Hoen[3]

Abstract

Rolling of steel requires a high input of energy and equipment. Thus, the efficiency of plants and machinery is of great importance for an economic as well as for a resource saving production also for cold rolled steel. As system supplier for integrated solutions in steel making and rolling mill technology SMS Siemag has developed a number of suitable systems that help plant owners to achieve an increment of efficiency and an economic and resource-saving production. The paper shows examples of efficient solutions for cold rolling mills. These are: T-roll process model for process optimization and efficient lubrication as well as developments in measuring systems and cleaning technologies.

Keywords: Cold rolling mills; T-roll; Total Roll Gap Control (TRC®); T-Clean; ECOFinish skin pass mills; ECOLub; Residual oil measurement.

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2 *Dipl.-Ing., Executive Vice President, Cold Rolling Mills Division, SMS Siemag AG, Germany.*
3 *Dipl.-Ing., General Manager Plant Technology and Innovation, Hot Rolling Mills Division, SMS Siemag AG, Germany.*

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1 INTRODUCTION

Protecting the environment is a key challenge for this millennium. Steel as an essential material in the global economy plays a crucial role in achieving the global goals of environmental protection.

Steel is a life-cycle material. On the one hand, as an energy intensive process, steel production accounts for 3-4 % of global greenhouse emissions. On the other hand, the material properties of high strength at minimum weight have saved millions of tons of emissions.

SMS Siemag has been working with steel manufacturers for over 100 years to improve emission and output. Technologies by SMS Siemag combine both, high-level environmental protection and maximum value for the customer's production process.

Although there are higher absolute saving potentials in other parts of the metallurgical process chain, the demand for increasing energy efficiency also exists for the cold rolling process. When discussing measures for reduction of energy consumption, the influence on product quality and process stability carefully has to be taken into account to really ensure an overall benefit. Evaluation of the underlying mechanical, thermal and tribological interactions affords a deep understanding by means of a physically based process model.

Therefore in the first part of the paper the energy saving potential of the cold rolling process, focusing the roll gap and an efficient lubrication, will be discussed theoretically, using the T-roll model, which practical relevance has been proofed by application of experimental data and laboratory investigations as well as by data from industrial cold rolling plants. In the second part, examples of other measures to improve cold rolling efficiency are given. All solutions shown are suitable for application in new as well as in existing mills.

2 EVALUATION OF ENERGY SAVING POTENTIALS IN THE COLD ROLLING PROCESS(1) APPLYING T-ROLL

In Figure 1 a schematic simplified representation of the energy flow in the cold rolling process is shown for one mill stand. Other energy contributions which are not directly process related could also be relevant, like for example the consumption of the fume exhaust system.

The ingoing energy consists of the work of the main mill drive and the difference (which also could be negative) of the strip tensions, related to the coilers or neighboring stands. Reduced by gear and bearing losses this energy is available for the deformation process, which affords the ideal (frictionless) deformation work and the roll gap friction work. Nearly all of this work is transformed into heat which goes into the strip, the cooling/lubrication media or the mill stand.

For a given cold rolling task (fixed yield stress curve and strip thickness reduction), the ideal deformation work is fixed and can only be reduced by the softening behavior of many metals at elevated temperature. The other contribution to energy reduced total deformation, on which focus is put in the following, is the roll gap friction work, which could strongly be affected by the tribological situation in the roll bite. Thus improving the tribological situation is the main key to decrease energy consumptionin cold rolling.

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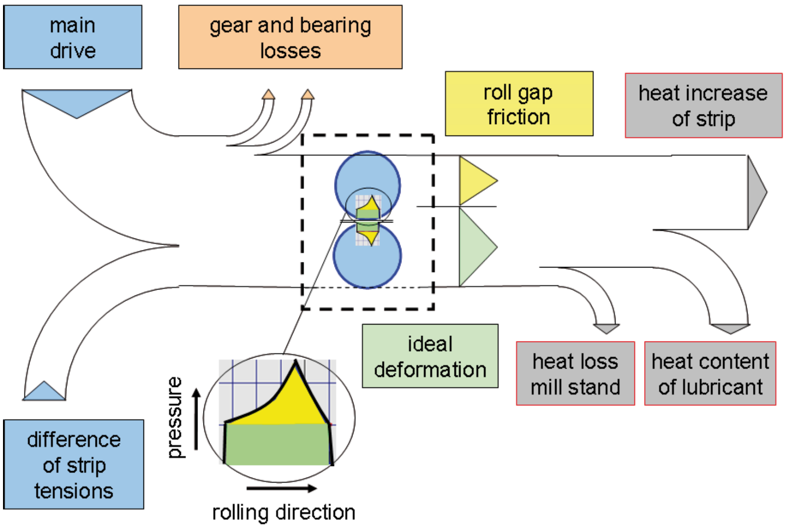

Figure 1. Process related energy flow in cold rolling.

2.1 Roll Gap Friction

Compared to other flat rolling applications in cold rolling, the friction coefficient μ between work roll and strip typically has significant influence on roll force, torque and power, because the ratio between contact length in the bite and strip thickness typically is large (Figure 2). Cold rolling takes place in the mixed lubrication regime, that means, there exist contact areas with boundary lubrication between surface asperities of strip and roll, and areas where lubricant pockets separate strip and roll.

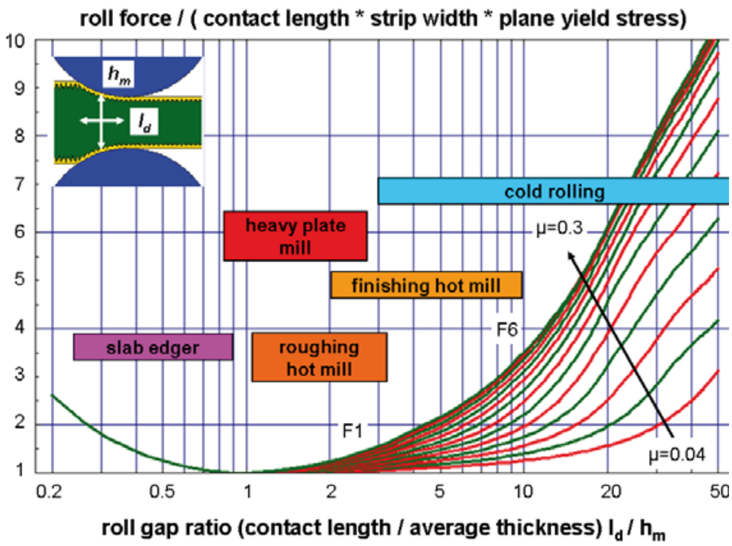

Figure 2. Influence of roll gap friction on roll force (work roll diameter 500 mm, thickness reduction 20%, average yield stress 300 MPa, non-circular-arc elastic work roll flattening considered)

Generally there are two ways to decrease the average (macroscopically observable) friction coefficient:

1. Decreasing the fractional area of contact for boundary lubrication or
2. Decreasing the boundary friction itself.

Decreasing the fractional area is reached by increasing the lubricant film thickness which is hydro dynamically drawn into the roll bite. However, an oil film which is too thick, compared to the roughness of strip and roll, may result in worse surface quality.

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Decreasing the boundary friction itself can be done by improving the additive composition of the lubricant. Usually this is more helpful, nevertheless changes of the tribological situation need to be done carefully, since low friction and thus low friction energy consumption is not the only criterion for process optimization, and too low friction even might be contra-productive. Some criteria are shown in Figure 3. Only understanding the mechanical, thermal and tribological interactions of the process by a suitable process model, like e.g. the SMS Siemag T-roll model, allows definition of suitable lubricant properties, resulting in a tailor-made lubricant formulation.

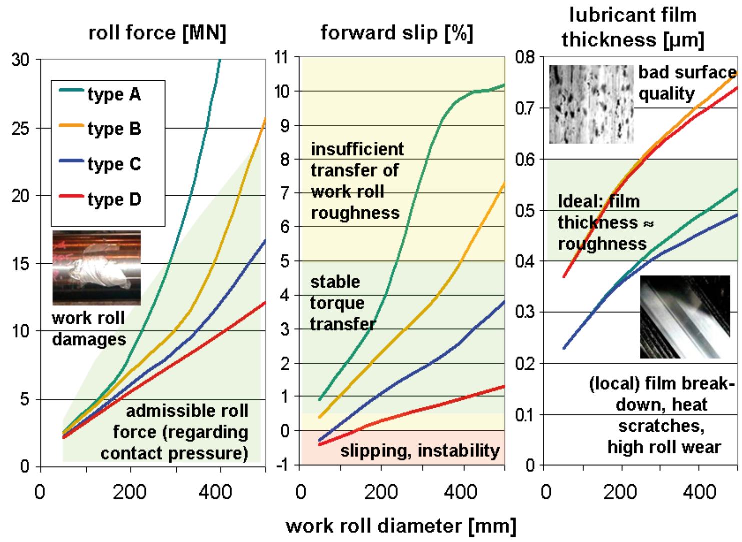

Figure 3. Criteria for lubricant properties, depending on work roll diameter (example parameters typical for cold rolling of high strength steel, strip width 1000 mm).

To evaluate and improve the boundary friction behavior of rolling oils and emulsions, SMS has developed an enhanced version of the friction measurement apparatus based on the strip drawing test. It allows the direct calculation of the friction coefficient from the measured normal and drawing force, figure 4. Plane strain deformation mode, relative speed between strip and tool, and strip temperature evolution are similar to cold rolling. Depending on additive content, large differences in friction behavior have been found. For illustration, two emulsions, which both have been used in industrial cold rolling applications, have been compared: the difference was approximately 25% (Figure 4).

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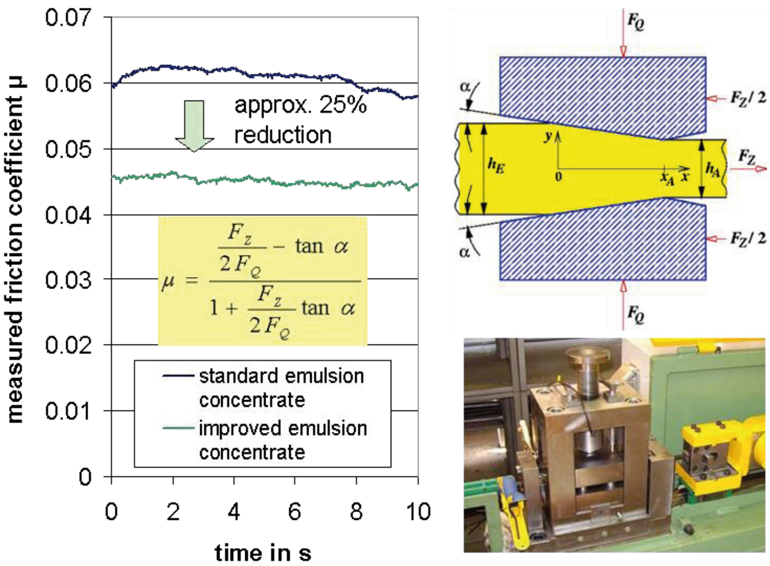

Figure 4. Potential for reduction of boundary friction coefficient by improving formulation of emulsion, measured with strip drawing test for cold hardened steel S235.

2.2 Energy Saving Potential in the Roll Bite

The measurements described above allow to evaluate the potential of roll gap friction reduction. Depending on the kind of cold rolling application and the currently used lubricant, the realistic potential of roll gap friction reduction is between 5 and 20%. To illustrate the total main drive energy savings by reduced roll gap friction, various rolling cases have been considered, based on an assumed friction coefficient reduction of 20%.

In some cases, besides reduction of roll gap friction work, the reduction of bearing friction losses, due to reduction of roll force, plays also an important role. It is even the major part for skin pass rolling.

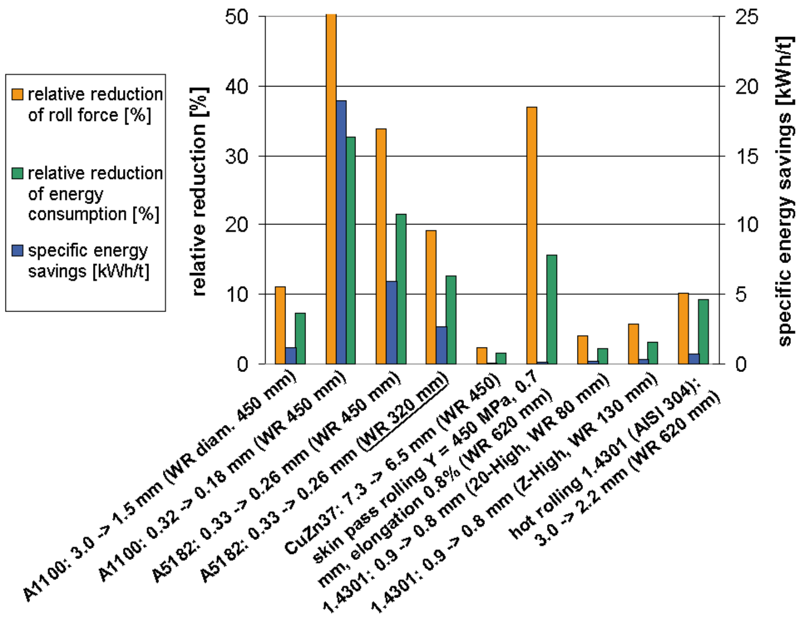

Figure 5. Energy and roll force saving potential for reduction of roll gap friction by 20%, power value normalized to 1000 mm strip width.

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Figure 5 summarizes the results of the discussion and compares the wide range of relative and absolute specific energy savings. The overview shows that relative savings are between 2 and 32%. This illustrates that optimizing the lubricant can be very beneficial but also other measures have to be considered to increase cold rolling efficiency.

3 PRACTICAL APPLICATIONS TO INCREASE EFFICIENCY OF COLD ROLLING

In recent years SMS Siemag developed a large number of innovative systems to increase efficiency of cold rolling mills.

Figure 6. Customer requirements and technological solutions by SMS Siemag

Some of them, like e.g. the TRC® threading assistance system for mills in batch operation, the CVC plus M18/4 multipurpose mill or plants for special steel grades were introduced to the ABM audience in recent years.[2,3] In the following ECOLub, as part of the ECOFinish skin pass mill concept, the innovative Dry Strip System T-Clean and the online measurement feature for detection of residual oil will be described.

3.1 ECOFinish Skin Pass Mills

To fulfill the requirements of the skin pass process and especially to reduce operation cost as well as to allow more resource saving operation, SMS developed the ECOFinish skin pass mill concept, which is based on four pillars:

- Alternative wet skin pass system ECOLub
- Modules of the T-roll model to ensure high accuracy, even under changing conditions
- Process-tailored lubricants by SMS Lubrication
- Extended Bending System EBS.

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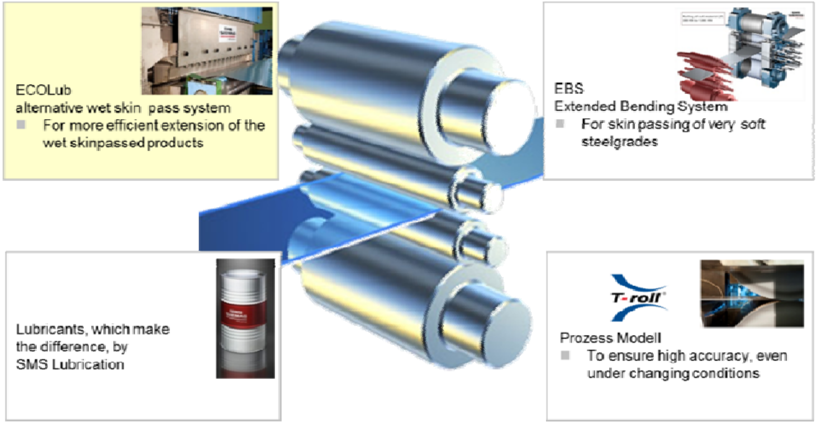

Figure 7. The ECOFinish skin passing concept by SMS Siemag.

In the following the innovative feature ECOLub is presented.

3.2 ECOLub Alternative Wet Skin Pass System

The innovative ECOLub system combines the advantages of wet and the dry skin passing. It is installed at the entry side of the mill and applies only the amount of lubricant which is actually needed in the roll gap.

The basic design of the ECOLub system is shown in figure 8. The main components are: oil and compressed air supply units, volume controller, nozzle beam and exhaust treatment.

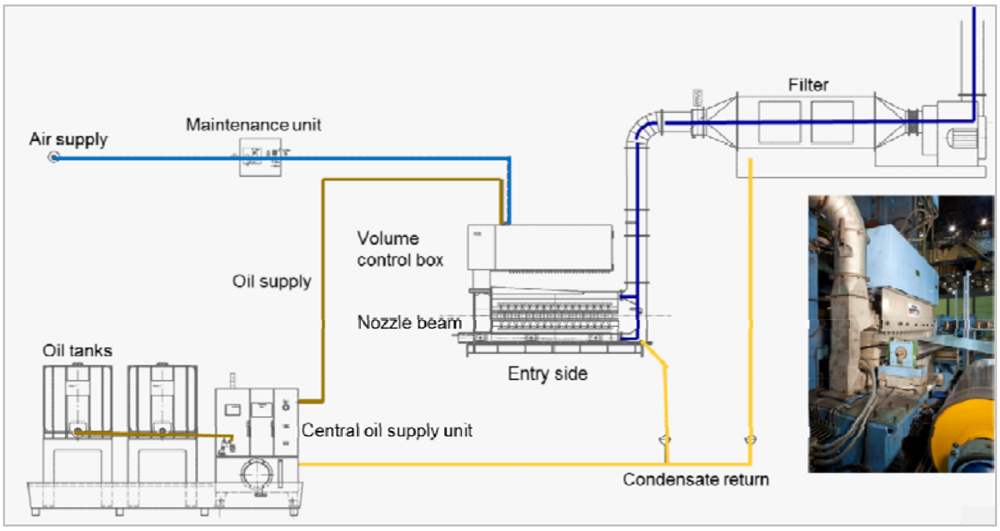

Figure 8. ECOLub system: media arrangement and exhaust treatment.

The lubricant is equally distributed by atomization with compressed air. Each nozzle of the nozzle beam covers a width of 100 mm. One or a group of upper and lower nozzles are combined in control units by using a volume controller.

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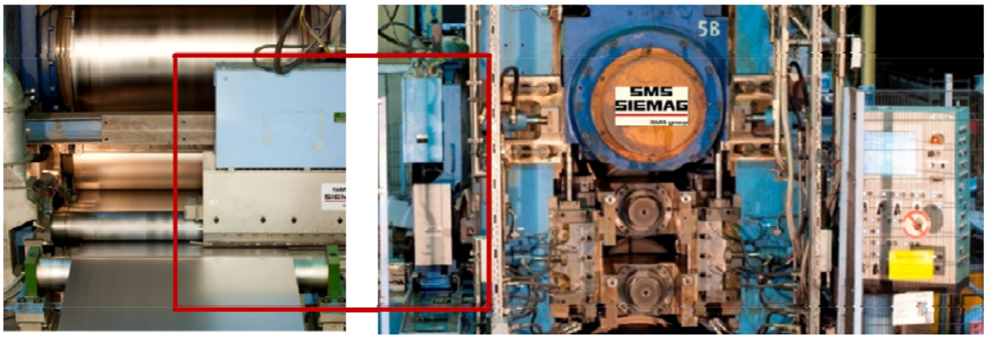

Figure 9. ECOLub system: entry side arrangement. The nozzle beam base frame can be removed manually or hydraulically from the mill stand area. Reference: SPM in a CAL, TKS Dortmund, Germany.

The lubrication reduces the friction in the roll gap and thus the rolling force and improves the strip flatness. Figure 10 illustrates the clear reduction of roll force by ECOLub for high strength steel strip (1,340 mm x 0.7 mm, elongation 0.7%), despite the fact that only top side was lubricated in the trial.

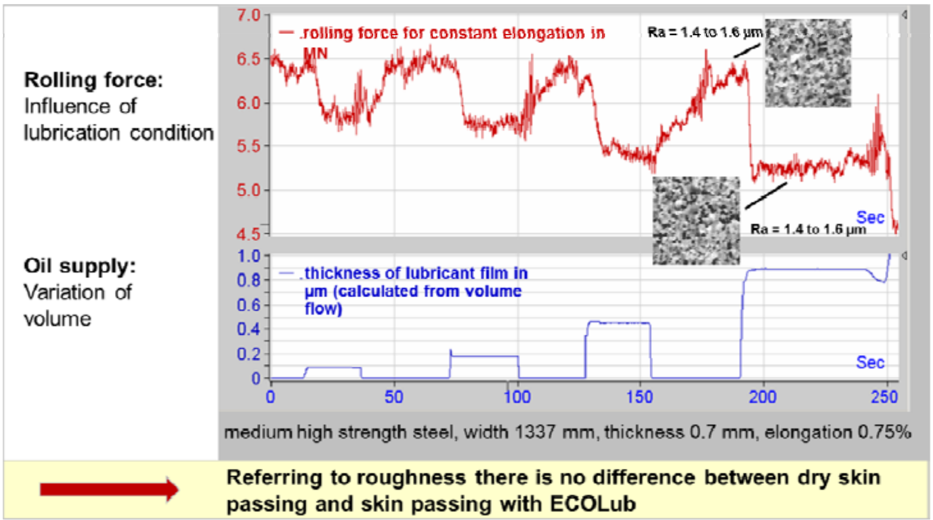

Figure 10: Roll force reduction depending on thickness of lubricant film (applied on top strip surface) at production test of ECOLub at skin pass mill in continuous annealing line of ThyssenKrupp Steel in Dortmund, Germany**.**

Lubricant pockets which lead to imprints of the lubricant on the strip do not emerge. As a consequence, many strips, which usually are dry skin passed, can be also wet skin passed by using ECOLub.

Figure 11 shows, for a given rolling case, an overview over the annual saving potencials by using ECOLub in comparison to a conventional wet skin passing system. The cost savings result out of lower consumption values and other costs, among other things these are skin pass agent, demineralized water, investment and residual oil treatment. In case of the given example, the savings add up to 200.000 € per year.

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Example	
Average strip width:	1,500 mm
Average rolling speed:	250 m/min
Average strip thickness:	0.7 mm
Annual production:	200,000 t/a
Use of lubricant	

Feature	Wet skin passing system	ECOLub
Consumption skin pass agent	approx. 1ml/m²	approx. 0.2 ml/m²
Consumption demineralized water	approx. 32 ml/m²	0 ml/m²
Investment costs	100 %	70 %
Add on existing plants	yes	yes
Recycling of residual oil necessary	yes	no
Quantity of nozzles at 1,600 mm barrel length	3	16
Annual cost saving for operational supplements up to 200,000 .-€		

Figure 11. Economic benefits of the ECOLub system.

3.3 T-Clean: Latest Generation Dry Strip (DS) System

Another chance to reduce costs in the downstream processes is to implement a Dry Strip system (DS System) at the exit side of a cold rolling mill. Using a DS System allows to omit certain cleaning treatments. The DS System will efficiently blowing emulsion, passing the roll gap, from the top and bottom sides of the strip and sucking away drops of emulsion at the edges, which results in the production of spot-free and dry strip.

SMS Siemag has two Dry Strip Systems in the portfolio: the compressed air type and the innovative blower type, called T-Clean. What both types have in common is that they are aerodynamically balanced systems with significantly reduced energy consumption. Because the compressed air type is characterized by a space saving compact design it is the preferred system to be retrofitted in an existing mill or within a framework of modernization.

T-Clean is a further developed DS System with increased cleaning efficiency and significantly less emission. T-Clean is based on blower. As a consequence, operation costs are lower in comparison to the compressed air type. Another benefit of T-Clean is the extended fume suppression at the exit of the last stand. The low noise level of 70 – 80 db, without additional cladding for noise protection, completes the list of benefits of T-Clean.

Figure 12. T-Clean: blower type Dry Strip system by SMS Siemag with extended fume suppression and low noise level.

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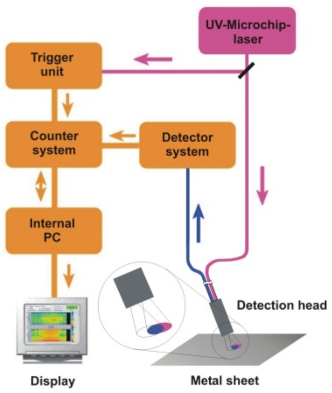
3.4 Online Measurement System for Residual Oil

Precise and continuous detection and recording of small amounts of residual oil on cold-rolled strip today are mandatory for quality assurance and efficient operation. Due to the nature of the process, it cannot always be prevented that oils are left on the strip after rolling. To prevent problems in downstream processing lines, for instance corrosion or “cracking” in the batch-type annealing facility, the amounts of residual oils on the strips should be monitored and minimized.

Therefore, SMS Siemag teamed up with Kienzle to jointly optimize the company’s online measuring system for use in our cold rolling mills. The result meets all the demands made on contactless residual oil measurement system.

The system includes one detection head on the top and on the bottom side of the strip, traversing across the strip width. The measuring principle is called laser-induced fluorescence spectroscopy. It uses laser light to stimulate the matter (oil), which transmits a characteristic light, when moving back in its ground state again. What is measured is the intensity of the light, which is an indication for the amount of oil. All components are designed for be use under rough mill conditions.



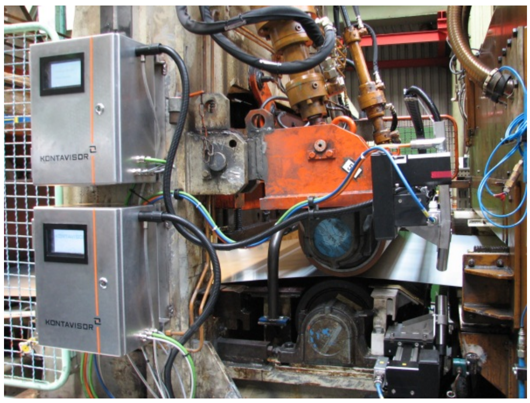


Figure 13. Functional diagram of the contactless online detection of residual oil (l); Application of the measuring system installed at TKS Rasselstein, Germany (r).

In practical use, our online measuring system offers a whole range of benefits:

- It permits continuous detection and documentation of residual oil over the width and length of the strips.
- It serves for quality assurance.
- It optimizes the consumption of lubricants.

Suitable additional measures enable to detect increased amounts of tramp oil resulting, for instance, from leakage in the hydraulic system.

Thanks to its small overall dimensions, it is excellently suited for subsequent installation in existing mills.

4 CONCLUSION

In the first part of the paper energy saving potential by optimizing the processes in the roll gap is discussed theoretically. As a result, it can be pointed out, that, depending on the rolling case, a significant amount of energy will be saved by using a tailored lubricant. With process model T-roll and special laboratory test SMS Siemag has developed the tool to explore this potential.

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However, also other measures are reasonable for an overall improvement of the efficiency of cold rolling mills. The following examples of SMS Siemag' s solutions were presented: ECOLub wet skin passing system, T-Clean DS System and residual oil measurement system.

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