Rolling oil technology for coupled and continuous tandem cold mills

The development and introduction of new rolling processes requires better performance oils as manufacturing demands become higher. The latest oil developments are able to simultaneously provide high lubricity and strip cleanliness as well as reduce the rolling oil consumption.

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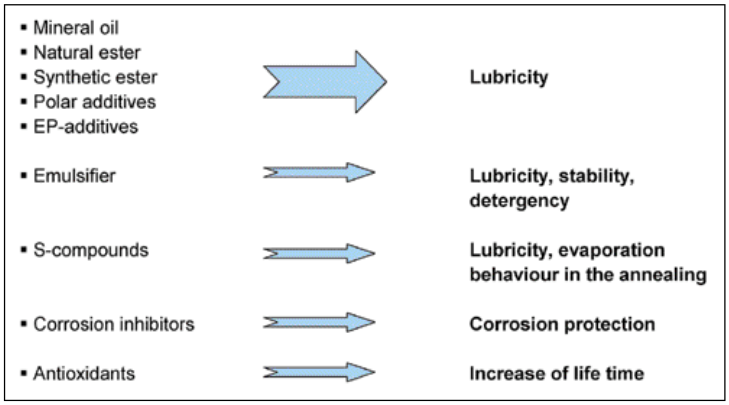


● **Figure 1** ***Components of rolling oils***

The steel industry has invested heavily in the modernisation of cold rolling mills, which are the focus of quality and productivity within cold mill units. The current requirements for the production of cold rolled strip in the steel industry are:

- High total reduction at high speeds
- The use of high-strength steel for lightweight automotive applications
- High surface quality and strip cleanliness
- Low processing costs
- Mill hardware cleanliness

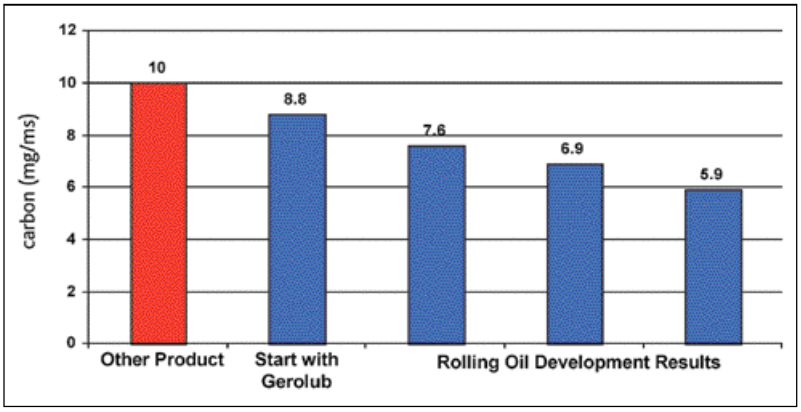
Henkel Technologies has met these challenges by developing new cold rolling oil technology, which gives very high lubricity properties, combined with high cleanliness and low oil consumption. The introduction of modern coupled and continuous tandem mills has placed added requirements on the cold rolling oils used. The entry strip is dry, work rolls in the first stand are usually smoother than with coil-fed tandem mills, and dirt generation has tended to increase. The extra dirt builds up on the mill stands and if the material becomes dislodged, it can cause strip defects. Thus, rolling oils with increased detergency are required. It has been found in practice that the new technology meets the requirements for both traditional coil-fed cold rolling mills and the new prestige coupled and continuous tandem mills.

Development of high-performance rolling oils

The following describes the developments undertaken to meet the cold rolling lubrication needs of both conventional coil fed mills and the very latest coupled tandem cold rolling mills. Traditionally, cold rolling oils for sheet are typically composed of the following:

- A lubricity base containing mineral oils, esters, polar additives and extreme pressure (EP) additives
- The emulsifier package, which mainly influences the emulsion stability (particle size), the lubricity via plate out and the detergency
- Sulphur compounds, which are very important in order to improve the evaporation behaviour in annealing. They also improve lubricity
- Corrosion inhibitors to prevent staining of cold rolled strip
- Antioxidants to maintain bath life of an emulsion and to reduce the effects of oxidation of rolling oil residues remaining on the warm coil after cold rolling

These materials are blended into completely formulated rolling oils with properties designed to match exactly the specific parameters of the individual cold mill. Particular care is taken to incorporate the correct ratio of boundary and EP lubricants to match the mill speed and deformation requirements of the steel strip. Chemical and physical tests ensure the correct ester level (saponification value) and viscosity. The emulsification is specified by two parameters: a desired oil droplet size and an emulsion stability index. These properties relate to system size and the



● **Figure 2** ***5 -stand tandem mill, carbon after batch annealing (HNX)***

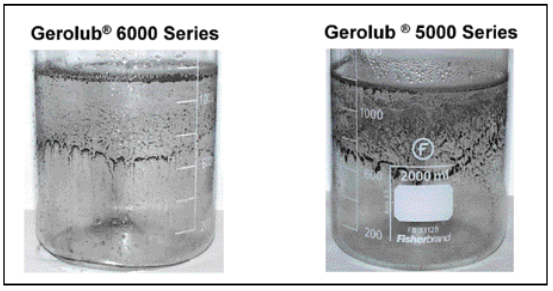
design and degree of turbulence within the emulsion tanks. The emulsification is critically important to give required oil plate out during the cold rolling process, and is a major factor in the rate at which rolling oil is consumed. The typical components of rolling oils are shown in *Figure 1*.

The required properties were optimised empirically and physically using sophisticated laboratory simulation methods and extensive testing and trials. Henkel rolling oils are marketed under the trade name Gerolub®, but are developed in close cooperation with each customer. Thus, every customer gets his own tailor-made product, which is individually engineered according to the specific demands. In the presented case, thermo-gravimetric tests were used to develop a rolling oil with enhanced evaporation rates of surface residues. *Figure 2* shows that a decrease of residual carbon after HNX annealing (annealing in an atmosphere of ~95% nitrogen and 5% hydrogen) could be achieved with the Gerolub 3000 series.

Henkel has further intensified its development of rolling oils. The products of the next generation, the Gerolub 5000 series, provide significantly increased lubricity properties, permit improved cleanliness of mill housing and steel strip, and maintain, or even reduce, consumption. This increased lubricity was obtained by changing a number of parameters:

- Introducing new extreme pressure components
- Increasing the saponification number
- Increasing particle size and thus plate out according to rolling requirements and the characteristics of the re-circulation system

The demand for good evaporation characteristics was not neglected, even though the rolling oil needed to be completely modified in order to improve the lubricity. Such engineered products can be operated in most cold rolling tandem mills anywhere in the world.



● **Figure 3** ***Increase of detergency***

However, a new coupled tandem mill presented a severe challenge for Henkel rolling oils. This mill was expected to be the latest design coupled tandem mill and it re-defined demands upon the cold rolling lubrication. The requirements for rolling oil working on that mill were:

- Further increase of lubricity (no use of pickling oil)
- Decrease accumulation of dirt and oil in the mill
- Avoid accumulation of dirt on the rolls
- Increase the cleanliness of the steel strip, especially for interstitial-free steels

The development was based on the positive experiences with Gerolub 5000 on tandem and reversing mills and finally led to the Gerolub 6000 range. The additive packages of the rolling oil were further refined to reduce high molecular weight and highly reactive components in order to significantly reduce the quantity of sticky residues, as indicated by the test results (see *Figure 3*).

The influence of certain chemical components greatly affects the nature of the residues remaining on the strip surface after cold rolling. Additionally, the detergency of the emulsion was increased to assist the wash-off behaviour as the strip exits each mill stand.

Due to a well-balanced selection of special sulphur compounds, polar additives and the emulsifier package, Henkel succeeded in increasing the detergency in order to get a cleaner mill housing and cleaner steel strip. This also benefits subsequent cleaning sections like prior to hot dip galvanising as the strip is easier to clean (see *Figure 4*).

Results of product introductions in different mills

The evolution of the technology can be followed by looking at the range of products, which are now operated at different mills, culminating in the successful introduction of the Gerolub 6000 series to coupled tandem mills.

Reversing mills For reversing mills the development resulted in the product characterised in *Table 1*.

Attribute	Value
Saponification number (mg KOH/g)	60
Acid value (mg KOH/g)	3
pH (2.5 % in demineralised water)	6.5
Density at 20°C (g/ml)a	0.916
Viscosity at 40°C (mm^2/s)	42
Emulsion stability, Emulsion stability index (Kenwood, 30s, position II)	0.88
Particle size M 1.3 (µm) (Sympatec Helos) Kenwood, 30s, position II, 2.5% emulsion	1.65
Lubricity Falex (concentrate), ASTM D 2625-94, max. load (lbs)	2500
SRV: Step test (100N/step, 50Hz; 1 mm; 100°C), max. load (N)	600
Thermo-gravimetric analysis (30mg; N2/H2: 95/5) residue %	< 0.03

● **Table 1** ***Product characteristics of reversing mill oils***

Together with several other rolling oils, the Gerolub 5000 series was first tested on a pilot mill where it proved to have superior lubricity, strip cleanliness, low residues and excellent evaporation behaviour. The Gerolub 5000 series is now successfully operated in several reversing mills.

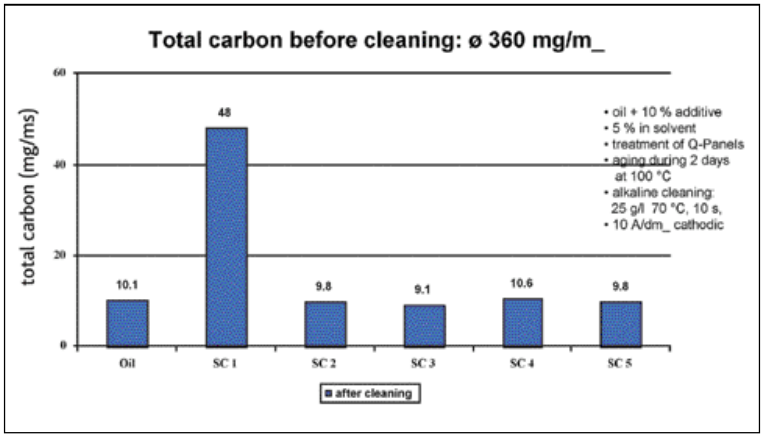
Discontinuous tandem mills The typical requirements for rolling oils in discontinuous tandem mills are high lubricity performance, a low total consumption, high active oil content and high cleanliness after cold rolling and batch annealing. Typical challenges like high oil leakages, the occasional lack of magnetic filters and low end thickness needed to be met and so a rolling oil of the Gerolub 5000 series was introduced.

During the lifetime of the emulsion, the rolling oil was modified in order to fulfil the requirements with regard to the elimination of the large quantity of leakage oil. The concentration of the oil in stands 1 to 4 is 2.0–2.5% and in the last stand only 0.5%. The results related to strip cleanliness after cold rolling and batch annealing are shown graphically in *Figures 5 & 6*.

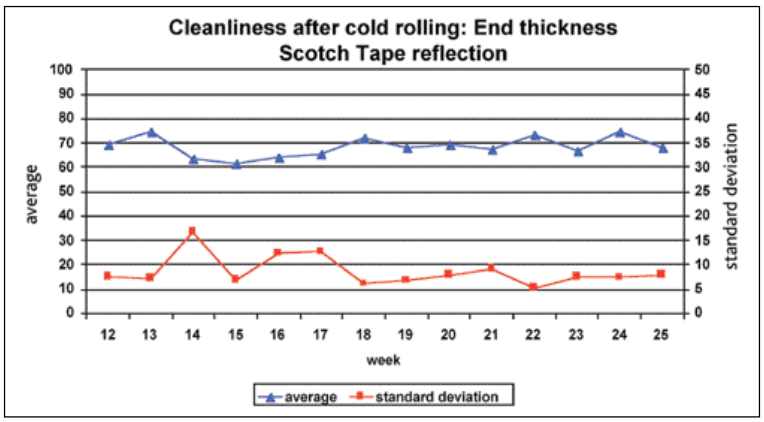
In addition to the usual emulsion analysis, such as concentration, saponification number, acid number, iron fines, etc, Henkel also measured the concentration of different rolling oil components. All requirements were fulfilled and the Gerolub 5000 series could be introduced to several discontinuous tandem mills.

Continuous mills Similar products to the Gerolub 5000 range, adapted to the specific mill conditions, were introduced to continuous mills. A decrease in consumption was obtained.

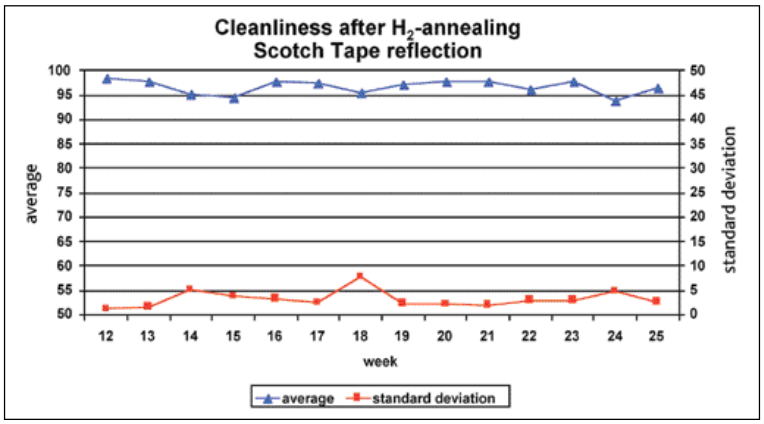
Coupled tandem mills As already described, the ultimate challenge was the development and introduction of a rolling oil suitable for running



● **Figure 4** ***Influence of high pressure additives on alkaline cleaning behaviour***

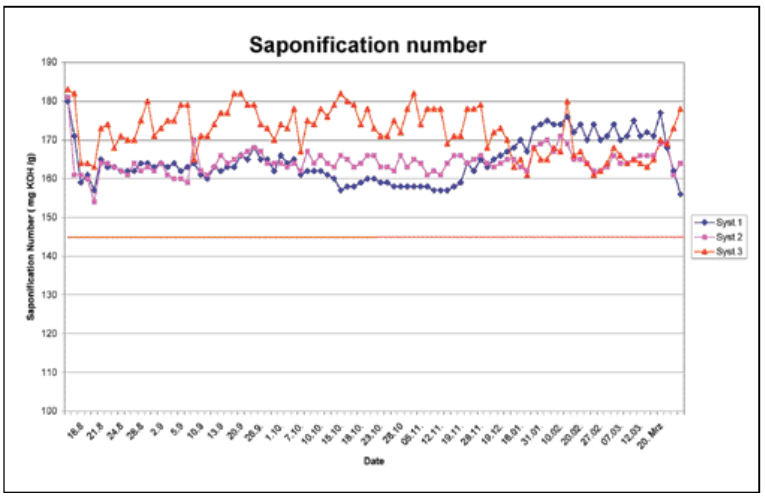


● **Figure 5** ***Discontinuous 5-stand tandem mill, Gerolub 5000 series***

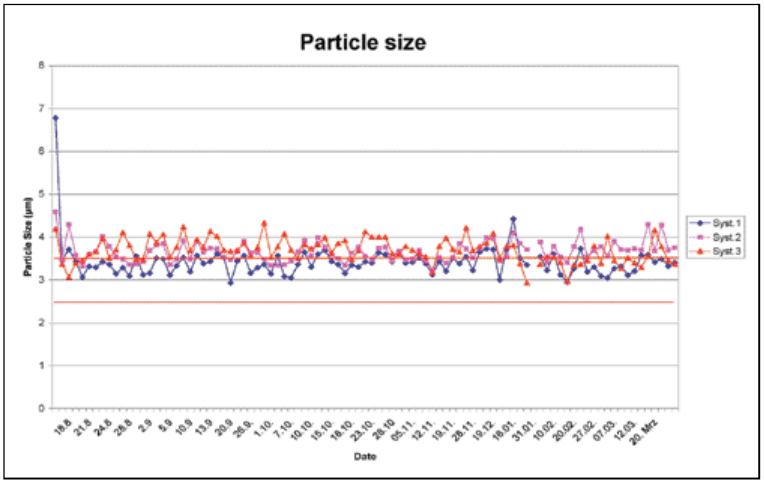


● **Figure 6** ***Discontinuous 5-stand tandem mill, Gerolub 5000 series***

safely in a new 5-stand coupled tandem mill. The re-circulation circuit consists of three systems: System 1 with 150m^3 oil capacity is connected to stands 1 and 2, system 2 with 150m^3 is connected to stands 3 and 4, and system 3 with 80m^3 is connected to stand 5. All three tanks use agitators. During the campaign, Henkel obtained a very constant



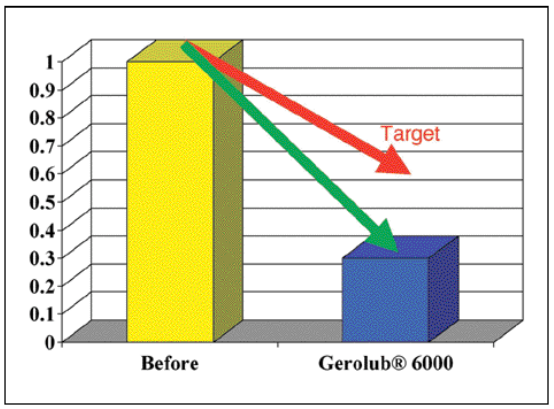
● **Figure 7** ***Coupled 5-stand tandem mill, Gerolub 6000 series***



● **Figure 8** ***Coupled 5-stand tandem mill, Gerolub 6000 series***

emulsion composition with a very high saponification number and constant high particle size as shown in *Figures 7* and *8*.

In the coupled mill it was possible to reach a very low oil consumption with the Gerolub 6000 series. The rolling performance was excellent and the cleanliness of the mill housing and especially of the cold rolled steel strip was significantly improved (see *Figure 9*).



● **Figure 9** ***Strip cleanliness***

Conclusions

Through new developments in the past few years, as well as very close cooperation with customers, it was possible to present individually engineered rolling oils for every mill. Through the evolution of the rolling oils to the latest products, the Gerolub 6000 series has shown significant improvement through the years. Practial examples prove that it is possible to simultaneously obtain high lubricity and high cleanliness as well as reduce the rolling oil consumption.

The original task of the development project was to meet the requirements of continuous and coupled cold rolling tandem mills. However, all mill types have benefited from the application of certain aspects of this project, which continues to meet the challenges of the continuously rising demands for increasing productivity, cost reduction initiatives and improved quality standards.

The newest generation 'high lubricity with high cleanliness' rolling oils are at the forefront of this work and continue to evolve as higher total cold reductions are made on tandem mills and as harder steel grades are produced.

Gerolub® is a registered trademark of Henkel

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