ULTRASONIC and HIGH-PRESSURE STRIP CLEANING TECHNOLOGY

METALLURGICAL PLANTS and ROLLING MILLS

STRIP PROCESSING

Technical Report
Hot and Cold Strip Processing
Dr. M. Kretschmer
INTRODUCTION

Essential customer demands for refined sheet products are good machineability in secondary manufacturing process and long term preservation of the final product. These qualities are fundamentally determined by the functional layer applied to the metal surface. The compound between the functional layer, e.g. the zinc layer, and the steel strip surface is primarily based on the adhesive strengths within the boundary surface. Deposits on the surface, such as abraded iron particles, oil or rolling emulsion remains, disparage the adhesion. The functional layer is not able to adequately fulfil the purpose. It is only irregularly applied or is easily removed under mechanical pressure.

In order to peel off the disturbing adhesions from the steel strip surface before it enters the refining process, the strip comes into intensive contact with the alkaline cleansing agents in the cleaning section. The strip refining of a hot-dip galvanizing line is usually composed with a combination of various alkaline cleaning processes and a concluding aqueous rinsing.

STATE OF CLEANING TECHNOLOGIES AT SMS DEMAG

Hot-dip galvanizing lines use cold rolled steel strip as material. Cold rolled strips are burdened with rolling emulsion and rolling residues resulting from the rolling process. Deposits of about 500 mg/m² per side, consisting of rolling emulsions, abraded iron particles and other dirt are therefore likely. Steel strip burdened in this way has to be relieved of these residues resulting from the cold rolled process before it enters into further surface refining. In accordance with state of the art technology this procedure is executed in a multi-stage strip cleaning section. A combination of an alkaline spray cleaning with brush support for the removal of surface deposits, an electrolytic cleaning for deep pore cleaning and a final multi-stage rinsing with fully demineralised water is used in this section. Cleansing agents are aqueous solutions based upon alkali, tensides and phosphates.

Installations for strip cleaning of SMS Demag distinguish itself by the optimal symbiosis of high refining performances and economical use of resources. The construction design of the machinery guarantees the maximization of the whole refining performance. The coordination and application of fluid streams secures to minimise fluid and energy consumption.

The pre-cleaning section has vertical spray degreasing and a vertical electrolytic degreasing on its exit end. SMS Demag effectively achieves a long treatment line with but actually with a short length facility by this method of construction. Thereby, good refining results are attained and the building will not be unnecessarily long.

Special sealing systems at the roller breakouts in the form of labyrinth seals with collection troughs and return flows to the tank minimize the free outlet shapes for gases, fumes and fluids. The quantity of sealdrains is minimized by well-aimed suck-off in
the region of the free outlet areas that leads to energy savings. Tank covers are sealed by a water seal so that a suction of separate air can be avoided. The tank covers are carried out in form of a roof to prevent the drain of condensate.

The partition walls of the process tanks are equipped with “u”-shaped collecting troughs to avoid formation of drops. The transitions of tanks are fitted with special systems for the prevention of fluid and steam loss.

The high mechanical cleaning effect in the spray sections is caused by the nozzle characteristic (nozzle arrangement on the pipe, spray angle, big spray drilling and by that optimal energy use of the spray radiation). The well-balanced pressurization of the medium onto the strip is enabled by the optimal selection of the nozzle characteristic. Nozzle pipes without blockage are guaranteed by the use of tongue nozzles. The nozzle pipes are laterally extendible and can be exchanged during operation. The applied setting secures that the adjusted spray angle is retained after the changing. A maintenance-low operation with slight energy losses is the net effect. A well-balanced pressurization of the medium onto the strip arises by the pressure distribution. Herewith a high mechanical cleaning result and a low evaporation of the fluid are combined. Consequently the aerosol losses are minimized.

The brushing machines distinguish themselves by their robust construction and running smoothness. Material damages and traces on the strips are thereby prevented. Furthermore a long service life of the brushes with a low spare parts consumption and maintenance expenses are a result. The basic advantage of the brushing is the construction of the brushing power system. The power is applied on the brushing roll neck by bellow cylinders which centrally put the load onto the bearings of the brushing rolls. This design prevents the bending of the brushing rolls and guarantees the calm operation of the brushing machines. The wear of bearings is reduced and chatter marks are avoided. The bearings of brushes and rolls are sealed. Short changing times (approx. 30 min per roll) for brushing roll and counter roll contribute to the easy maintenance.

The electrolytic degreasing has an excellent cleaning performance by the use of high current density and an optimal electrolyte guide way. The flow path of the mediums from downwards to upwards through the process tank supports the degasing of the produced hydrogen, avoids formation of gas nests in the process tank and minimizes the foam production. The construction and performance of the electrodes realize minimal electric resistance loss. The optimized degasing and minimized foam production facilitate to operate the electrolytic cleaning with high current densities up to 20 A/dm². The vertical strip flow ensures a stable, defined position of the strip between the electrodes without sagging.

The cascade guiding of the cleaning medium in the strip cleaning installation guarantees a continual, high cleaning quality. Special equipments for the fluid maintenance, especially the suitable installation of magnetic chain filters, ensuring the maximum efficiency of the strip cleaning.

The rinsings are arranged in cascades and combine a modest waste water amount and fresh water consumption with an excellent flushing effect at the same time. The last rinsing cascade is operated with totally demineralised water. The process tank is equipped with tongue nozzles in the spraying header and runs with a process pressure of 10 bar in the last rinsing cascade to achieve a high rinsing effect.

The combination of strip edge blow-off and strip dryer after ending the strip cleaning guarantees a complete and over the whole strip width homogeneous and cost efficient drying of the strip surface to end the spreading of fluids.
Due to continual contacts to the user and based on data and experiences from running production lines a permanent development of our technology takes place. Moreover SMS Demag is in the position to independently optimize existing process technologies and applications of new products at our Technikum plant.

On the top of this SMS Demag is partner for the Dortmunder Oberflächen-Centrum (DOC), keeps an experimental plant for testing forward-looking processing methods and new processes (feature 1). Owing to these opportunities SMS Demag has the ability to offer the optimal process for each plant design.

It is known from the cleaning of individual parts that by increasing the mechanical energy influence onto the surface in question, e.g. in the ultrasonic and high pressure processes, an essential improvement in cleaning effects can be achieved. By using the ultrasonic and high pressure cleaning a clearly lower ecological damage can be expected. The quantities of waste water in the production process “surface refining of steel strips” are noticeably reduced by the perceptible lower requirement for cleaning agents and the optimizing of the circulatory guidance of the strips in combination with the possible use of the diaphragm technology for additional fluid conditioning. Positive knowledge regarding the adaptation of the ultrasonic und high pressure process at the pilot plant for strips in the Dortmunder Oberflächen-Centrum (DOC) is on hand.

SMS DEMAG INNOVATIONS IN THE CLEANING TECHNOLOGIES

The potential for innovations in the conventional cleaning technologies lay in the reduction of the energy requirements, the minimized chemical use and the lower expenses for wearing parts, e.g. by the renunciation of the brushes.
The central component in the high pressure cleaning is the relevant pump. A Pitot pipe pump is chosen for high pressure pump package (Feature 3). Already this kind of pump is successfully used for the cleaning of different steel strips in the pilot plant for strips in the Dortmunder Oberflächen-Centre. The mode of operation of the pump is discernible in the basic plan. The medium enters the pump chamber via the suction socket. In contrast to customary centrifugal pumps the pump chamber at this pump is the rotor. In the rotating pump chamber the medium is brought on a very high rotary velocity. In the rotating fluid body is the fixed Pitot pipe. In this pipe the (kinetic) rotary energy of the medium is transformed into (potential) pressure energy. The high rotary velocity of the medium causes a fluid pressure above 100 bar at the pressure socket.
The cost efficient use of the high pressure cleaning requires the circulation of the cleaning medium through the high pressure pump. The cleaning media is a multiple phasing fluid, consisting of a fluid phase of the cleaner and included gas or foam bubbles. The foam formation in the medium can not be totally excluded with the use of an alkaline, tenside-containing cleaner. In centrifugal or reciprocating piston pumps even small gas parts in the medium lead to cavitation appearances in the pump chamber and with that to the breakdown of the pump within a short time. A Pitot pipe pump has been selected due to its relatively high insensitivity against gas/foam (gas part < 10 Vol. %) in the pumping fluid. In result of the spread of pressure the gas parts collect themselves in the centre inside the fluid body where they do not get in contact with the changed pressure conditions in the outside standing Pitot pipe. In the pump room a fast rotating fluid ring with a gas bubble in its centre of rotation is formed. The additional separated rinsing of the flinger seal reduces the wear by particles in the medium.
TECHNOLOGY OF THE ULTRASONIC CLEANING

The ultrasonic cleaning combines the cleaning of the surface by active processes on the surface (lipids in the strip cleaning medium) with the mechanical removal by kinetic energy of imploding gas bubbles. The ultrasonic oscillations lead to local pressure fluctuation in the fluid. In sections where the pressure goes below the gas pressure of the released gas or the steam pressure of the fluid, tiny cavitation bubbles develop. The bubbles rapidly implode because the artificial conditions which lead to the forming of bubbles only exist for a short time. The shock waves which are induced by the implosion of the gas bubbles (especially on the strip surface) blast away the dirt on the surface. Surface layers which are loose become removed. More stable layers are broken up by shock waves and also washed away. The lipid parts in the added strip cleaner partly support the cleaning process. The main function of the lipids is the binding of the removed dirtying in the fluid.

Cleaning with ultrasonics has the big advantage that beneath the high quality and reproducibility of the cleaning results materials can be cleaned mechanically without any contact. Depending on the cleaning requirement you can therefore abstain from aggressive chemicals and high temperatures. The chemical additives (cleaning agents) which support the aqueous ultrasonic cleaning are added in a low percentage and are similarly important in the choice towards the required ultrasonic performance and the working frequency. Depending on the field of application the ultrasonic cleaning produces a high-quality and homogeneous cleaning result that can not be achieved by any other cleaning process.

The ultrasonic oscillation technology used requires no special bath conditioning. The vibrators are capsuled in a stainless housing. The housing material can be suited to the bath medium. The process tank is executed as a sink tank to have enough medium at its disposal to transmit the sound waves onto the strip surface. Only a moderate flow rate has to be adjusted in the sink tank so that the bubbles formed do not flow away immediately and / or to hinder the sound waves in their propagation.

EFFICIENCY OF THE HIGH PRESSURE AND ULTRASONIC CLEANING TECHNOLOGY

Efficiency and quality of the high pressure and ultrasonic cleaning technology has been examined in different tests at the pilot plant for strips of the DOC and at the hot-dip galvanizing line of Thyssen Krupp Stahl AG in Bochum. The technological cleaning in the pilot plant for strips of the DOC essentially consists of a pair of high pressure spraying headers and an ultrasonic cleaning tank. Detailed tests have confirmed that the cleaning efficiency for different kinds of steel strip is improved over the conventional strip cleaning section. Tests in the hot-dip galvanizing line of Thyssen Krupp Stahl AG in Bochum have confirmed this potential under industrial conditions. These results will be exemplary discussed twice in the following, a cold rolled multi-phase steel strip and an electrolytic tinned steel strip.

The degree of cleaning for rolling emulsion and iron abrasion was separately analyzed and presented. Feature 4 shows the degree of cleaning of the high pressure and ultrasonics in relation with the rolling emulsion plate as a function of the strip speed depending on the method of plant processing. Feature 5 demonstrates the degree of cleaning of high pressure and ultrasonic cleaning in relation with iron layer as a function of the strip speed depending on the way of plant processing. A duplex-grain steel, a so called high-strength multi-phase steel, was used as substratum. This kind of steel is hard to clean on occasions.

The degree of cleaning falls down with the increasing strip speed. Higher quantities of dirtying applied via the strip surface can only be removed partly. The cleaning technologies used have different influences on the respective cleaning results. The high pressure cleaning alone removes 80 % of the rolling emulsion layer at minimum. The iron pollution alone can be reduced by 92 % at the minimum by this technology.
The ultrasonic cleaning as fine cleaning has its strength in reducing the burden of rolling emulsion. The cavitation of the bubbles produced on the surface blows up and removes tiny emulsion remains out of the technical surfaces. The additional cleaning effect by the parallel use of the ultrasonic and the high pressure cleaning is lower for the larger iron particles which mainly lay on the strip surface because of their size.
The following investigations were carried out on galvanized sheet with a corrosion protective oil layer. Both cleaning sections were operated with a tenside cleaning agent. Feature 6 shows the possible cleaning grades independent of strip speed, cleaning concentration and operating practice of the strip cleaning sections. By increasing the strip speed the grade of cleaning decreases. By means of the strip surface larger contaminants are taken into consideration which consequently leads to the decreasing exposition time and can only be partly removed. It becomes obvious that also the cleaning agent concentration has influence on the efficiency of the processes. The investigations with annealed strip showed that the effectiveness of the process above a minimum limit is mostly independent to the composition of the bath. For the case of electrolytic-galvanized strip surface the degree of cleaning increases with the increased concentration of the additives in the ultrasonic cleaning. If cleaning-active tensides in a separate quantity, which is above the cleaning concentration added on top, the cleaning efficiency increases further. The best cleaning degree can be achieved by using a combination of high-pressure and ultrasonic cleaning. The start of the first cleaning step causes another increase of the cleaning efficiency by approx. 5 to 10 %.
The efficiency of the high-pressure cleaning technology was confirmed significantly in our first industrial application. The existing strip cleaning installation of the hot-dip galvanizing line at Thyssen Krupp Stahl AG was equipped with a high-pressure module. The high-pressure module was operated with cold industrial water without addition of cleaning media. Only the kinetic energy of the high-pressure water blasts was sufficient enough to result in a significant improvement of the cleaning efficiency (Feature 7). At the same time a proof could be found for the fact that the increase of work pressure does not necessarily
imply the improvement of the cleaning result. The increase of jet pressure from 80 bar to 100 bar implies a provable improvement of the cleaning quality. But a further raise of the pump power from 100 bar to 120 bar has negative implications. The result is an intensified streaking on the strip surface because the water jets start overlapping further and preclude their cleaning performance. The working pressure of the high-pressure module can be adapted by the design of the spraying header and the choice of spraying systems optimal to the environmental conditions.

LINE CONCEPT

In the first part of the strip cleaning section (feature 8) the strip is processed to the necessary temperature and the surface soils are cleaned away by the hot alkali cleaning solvent. In the spray degreasing section the strip is sprayed upon intensively with the hot cleaning media in order to heat it up to the requested temperature level and to remove coarse, adhesive contamination. The brush degreasing removes contamination on the strip surface by means of several rotating brushing units. The electrolytic degreasing removes contamination by means of direct blistering on the strip surface which are deeper in the topography. The following brush rinse brushes off tiny remaining contaminations from the strip surface. Then the strip surface is rinsed with hot demineralised water in order to wash away the cleaning solvent completely.

With good frame conditions cleaning degrees up to approx. 90 % can be achieved in the relevant strip cleaning sections. This means the initial contamination of the steel strip are reduced down to approx. 10 %. In the area of brushing aggregate and the electrolytic degreasing there is some optimizing requirement. The mechanical contact of the bristles and the strip surface results in a wear of the brushes which is related to future continuous costs. The removal process with the high-energetic water headers in the high-pressure cleaning does not imply a direct mechanical contact and is therefore completely wear free. The electro-chemical process in the electrolytic degreasing requires a costly design of the process containers. In addition the production of oxygen and hydrogen gas in the process implies another safety risk. With the omission of the electro-chemical reaction in the ultrasonic cleaning the design of the process container is much simpler. The emission free, mechanical removal process is not subject to special requirements for the container exhaust and is therefore with regard to safety uncritical.
In different tests the efficiency of the high-pressure and ultrasonic cleaning technology has been examined. Because of these examinations it has been possible to find out that the technically soiled (contaminated) steel strips can be cleaned with a very good result via high-pressure and ultrasonic cleaning. The high-pressure cleaning provides a good coarse cleaning. The kinetic energy of the high-pressure jet of water works on the surface coatings, causes cover layers to be removed. Contamination which is deeper in the topography of the technical surface are loosened by the ultrasonic cleaning and cleared away. The formation and implosion of tiny gas bubbles on the strip surface which is due to the ultrasonic vibration blasts adhesive coverings off.

Based on these test results the following cleaning concept was developed and focused upon (feature 9). The arrangement of the strip cleaning section stays in general the same, but expanded by a high-pressure and ultrasonic cleaning section. The brush degreasing and the brush rinsing are being substituted by a pair of high-pressure spray headers each. The electrolytic degreasing section becomes a ultrasonic cleaning section by means of exchange of the electrode systems by respective ultrasonic systems.

High-pressure cleaning technology, as an alternative solution, eliminates the costly use and maintenance of brushes.

Ultrasonic cleaning in parallel to electrolytic cleaning uses less energy to achieve the good cleaning results. The compact design of the process technologies opens new opportunities for the construction and design of space-saving high-pressure cleaning systems in strip processing lines.
OUTLOOK

The results of our investigations have shown that high-pressure and ultrasonic systems can be equipped for the cleaning of steel strip before the surface refinement process with good success. The task of the research projects, to minimize environmental pollution, resulted in improvement to the product and a reduction in production costs, giving major benefit.

With the use of the high-pressure cleaning technology as substitution for the mechanical brush cleaning, operational costs for spare brushes are abandoned which as wear parts have to be replaced regularly. The ultrasonic cleaning as parallel to the electrolytic cleaning consumes far less energy to reach the required cleaning result. The compact design of the process technology opens new opportunities for the design and construction of space-saving strip cleaning sections in strip processing lines (feature 10).

Additionally it was shown that due to the increased efficiency of the strip cleaning with the innovative and new cleaning process relevant savings with regard to the amount of cleaning chemicals can be achieved. The environmentally important components (tensides, phosphates, etc.) in the cleaning agent itself can be significantly reduced. The cleaning of the waste water can be operated at lower cost and energy use.
SUMMARY

Expansion of the spray degreasing by a high-pressure module

- Last spray header as high spray header
- Omission of brush cleaning => wear free surface cleaning

Substitution of electrolytic cleaning by ultrasonic cleaning

- Significant reduction of energy requirement
- Easier container design
- No extensive safety technique and exhaust

High-pressure module as last cleaning step despite of brush cleaning

- Omission of brush cleaning => wear free surface cleaning

Customer profits

- No abrasive cleaning procedure necessary anymore
- Shortening of line length by approx. 25%
- Approx. 10% less investment costs
- Less energy expenditure due to omission of electrolytic cleaning
- Usage of the existing media cycles
SMS DEMAG AG
Strip Processing Lines Division
Walder Strasse 51-53
40724 Hilden · Germany
Phone: +49 (0) 211 881-5911
Telefax: +49 (0) 211 881-4212
E-mail: matthias.kretschmer@sms-demag.com
Internet: www.sms-demag.com