Furnace technology from the rolling mill designer and builder

by Thilo Sagermann

In the steel and aluminium industries, it was standard practice for many years for investors to split orders for new rolling mills or strip processing lines into three different packages, namely mechanical equipment, electrical equipment and thermal treatment, and to award them separately. It was the task of the investor to coordinate the individual packages and to assume responsibility for the interfaces arising from these. However, the customers are becoming increasingly interested in plantmakers who are prepared to supply the overall integrated plant including process know-how and who are technologically capable of doing this.

Some years ago, SMS Siemag gradually started to change this long-established practice of splitting orders into packages, firstly by combining the mechanical and electrical equipment packages and, more recently, the furnace technology, into one complete supply. This serves to bring the manufacturing process into the foreground. This results in major advantages for both parties: The owners now need to be responsible for fewer interfaces and, by emphasizing the process responsibility of the plantmakers, are able to make the latter accountable not only for the functioning of the plant but also for the resulting product. This market development has provided an opportunity to expand as a result of the expansion of the business itself and, vis-à-vis the competitors, to exploit the benefits offered by assuming the overall responsibility. This trend commenced when SMS first began to supply the complete plant.

Fig. 1: Two Drever continuous annealing furnaces in the hot dip galvanizing plants of TKS in Alabama, USA
the drive engineering and control electronics on the basis of its strong experience in mechanical plant engineering. This rapidly led to the development of process models, for example for ensuring constant strip dimensions and flatness. Thus, it soon became possible to influence the geometry of a rolled product and to guarantee this geometry. The influences of the thermal treatment on the properties of the rolled product, however, continued to be an open question. The company regarded this deficit as a challenge to be dealt with on the market and searched for a solution that would integrate the heat treatment of rolled products into its own portfolio.

NEW DIVISION “FURNACE TECHNOLOGY”
The decision to establish this new division was already taken five or six years ago. This decision was triggered by the acquisition of the Belgium-based company of Drever International, which was already a long-established leader in the construction of furnaces for continuous strip processing lines such as annealing and galvanizing lines for carbon and special steels. It continues to be a leader in this field.

The driving force for entering this sector came from the Strip Processing Lines Division which, in earlier times, had always awarded the furnaces portion of orders for integrated plants to sub-suppliers or consortium members, including Drever. Here in particular, it became evident to SMS that the various types of processing lines for steel strip all comprised an essential process step. This critical step, which defines the material properties of the product and requires a great deal of know-how, takes place in the furnace and during the downstream cooling process.

At SMS the people are convinced that anyone who does not understand the processes underlying the heat treatment of strip will not be able to offer the customer any added value. And this must go beyond a mere consideration of the interfaces between the processes. Fritz Brühl, Executive Vice President of the new Furnace Technology Division at SMS Siemag, says: “Clients are increasingly tending to rely on our expertise to achieve specific material properties. In the long term, the only companies who will survive in the marketplace are those which can reproduce the process in its entirety. This applies, for example, to modern steel grades such as TRIP and dual-phase steels. These materials cannot be produced without using a well-targeted heat treatment.”

In the succeeding years, the market has provided an ever greater number of new and varied tasks relating to the heat treatment of semi-finished rolling products to be dealt with by the company. At first, besides the continuation of Drever’s successful business, that firm’s general furnace know-how was utilized for new developments. This resulted in SMS itself becoming increasingly knowledgeable. Such knowledge was mainly developed in close cooperation with the Strip Processing Lines Division, which was responsible for the mechanical equipment. This process of transition led to the formation of the new division, Furnace Technology, at the beginning of 2011.

SMS Siemag is well known as a successful supplier of rolling mills and strip processing lines for flat products. It was therefore taken for granted that the new business unit would likewise concentrate on the field of heat treatment for flat products. Brühl expresses this succinctly: “There are two terms that describe our product portfolio: One of these is called heat treatment and the other is flat material. In our opinion, added value and technological challenge are less likely to be found purely in reheating, but more in heat treatment, i.e. heating and cooling of the material in a targeted manner.”

The new division has positioned itself successfully on the market within a very short time. Thanks to the many new and further developments and to the close cooperation with the Hot and Cold Rolling Mills and Strip Processing Lines Divisions, a large number of orders have been obtained which are of consistent importance of the future of the division. The division, with headquarters in Düsseldorf, already has around 250 employees worldwide.

Thanks to target-oriented further development, the division has until now been able to draw upon its Europe-based resources to implement the following main areas of application for the firm’s own furnace technology for flat products made of carbon and special steel grades and for electrical steel strip:

- vertical and horizontal furnaces for continuous annealing and galvanizing lines,
- floater furnaces for coating and annealing lines,
- heat-treatment facilities, roller hearth furnaces and batch-type furnaces and
- technology for CSP plants of the latest generation.

**VERTICAL FURNACES FOR CONTINUOUS ANNEALING AND GALVANIZING LINES**
Vertical furnaces from the Drever heat treatment range, i.e. for the annealing and cooling of steel strip, are an essential constituent of the new Furnace Technology Division and are a factor in its success (Fig. 1). The Drever furnace has been further developed with new technologies. For the furnaces, these developments primarily involve measures for enhancing the energy efficiency and avoiding nitrogen oxides (NOx) and, for strip cooling, the increasing of the cooling rate. The latter aspect is important not only for reasons of efficiency but also for the fulfilment of ever stricter requirements for the manufacture of high-quality steel grades, such as for automotive construction.

Cooling rates of 100 to 120 K/s per mm strip thickness represent the widely accepted state of the art. By means of a modified cooling system, Drever is aiming at an increase to 150 K/s. To this end, highly promising tests are currently underway on gas-jet cooling, which represents an enormous
further development. To implement this, Drever makes use of especially long cooling boxes which extend on both sides almost as far as the strip running through, and also of special outlets which influence the impact of the gas on the strip. Also of great importance in this context is the increasing of the hydrogen constituent from 15 to 30 %, which has been practiced by Drever for the past ten years. The critical question as to the apparently higher hydrogen consumption is pre-empted by Drever by referring to the special concept whereby the hydrogen is not introduced via each cooling nozzle but centrally and therefore very efficiently at only three or four places in the cooling chamber.

Cooling of the strip with water, which could not be done in a targeted manner 20 years ago, has today become a possible alternative thanks to modern process handling and new technology. SMS Siemag is currently commissioning a continuous annealing line, which again is equipped with a water quench, for the firm of Protec in the USA. Cooling rates of > 1,000 K/s should be attained here. The situation is different with special steel strips. For these, Drever uses an efficient water spray-cooling system.

Whereas until now annealing and galvanizing lines have been built as independent individual plants, SMS Siemag offers a solution for applications in which profitability and flexibility are of prime importance. In this solution, the two tasks of annealing and galvanizing are unified in a combined line. A fundamental aspect here is that the basic function of the furnace is comparable for both tasks and thus the furnace, as the most expensive unit in the plant, is required only once. SMS Siemag is currently supplying the third plant of this type, this time to the South Korean firm of Hyundai Hysco. The first combined line has already been operating since 2006, likewise at Hysco, and a further line since mid-2012 at MMK in Russia. Their chief utilization is the galvanizing of automotive strip. The annealing process is authoritative for the design of the furnace. The heat treatment during annealing and galvanizing is performed in a different manner in each case and does not require any alterations to the line when changing over. It has a similar structure to that of the hot-dip galvanizing line. Even so, following the annealing process in the furnace, the strip can be further-processed in two different ways. Firstly, as in the hot-dip galvanizing line, the still hot strip can be routed through a zinc pot, coated with liquid zinc and then cooled down. The other possibility is to convey the strip into an overageing furnace. Here, it is treated for up to 180 seconds at temperatures between 270 and 430 °C. This causes carbides to be dissolved out and the danger of ageing is minimized. Annealing is completed by final cooling and water final cooling. The combined line is thus equipped with a furnace which allows the production of the same high-quality grades as in a modern continuous annealing line. The conversion of a hot-dip galvanizing line into a purely annealing line takes only around 16 hours (Fig. 2).

A special status is held by heat treatment facilities for grain-oriented and non-grain-oriented electrical steel strip. Jointly with the Strip Processing Lines Division, the Furnace Technology Division offers a complete range of equipment for the complex manufacturing process for the above. This comprises annealing and coating lines (ACL), annealing and pickling lines (APL), and decarburization and coating lines (DCL). In these lines, the annealing technologies of the Drever furnace are combined with the operation of the floater furnaces after coating.

The concept put forward by SMS Siemag is that in future the plant owner will specify the mechanical and metallurgical properties of steel strips to be produced. As the supplier of the integrated plant, the company will then make use of models which illustrate the most suitable process as
regards temperature control during rolling and during the subsequent heat treatment. In order to design this process in a reproducible manner, it is monitored and controlled by means of measurements of the mechanical properties attained. A suitable measuring method, which is available from the company group itself, is the “Impoc” system from EMG. The corresponding trials currently being conducted by SMS Siemag on a production facility in Belgium are expected to lead to positive results. As a parallel activity, work is being conducted on the modelling of mechanical properties and on their measurability during the ongoing process.

FLOATER FURNACES FOR COATING LINES
Activities in the fields of heat treatment of thinner steel strips and of the drying of surface-coated strips in what are known as “floater furnaces” were commenced by SMS Siemag in 2011 upon the acquisition of the know-how and employees of the firm of GATV, with whom a long-standing cooperation in the steel field already existed. For example, GATV has supplied the drying furnaces for strip processing lines (Fig. 3).

GATV contributed perfected technology for floater furnaces and for free-loop furnaces for carbon and Si steels. A floater furnace performs not only heating but also cooling, which at GATV involves air and water. Only this way the high cooling rates can be achieved which are essential for setting the complex metallurgical properties of special steels.

SMS Siemag recently supplied two such floater furnaces to ThyssenKrupp Steel in Eichen, intended for the drying and hardening of the prime and finish coatings in an existing strip coating line. What was remarkable here was the plant shutdown of only four weeks, with only the terminal equipment for strip running being retained. During this period, the existing furnace modules were dismantled and the fully prefabricated new models installed and put into operation. The SMS Siemag supply scope also included the gas cleaning system and the electrical and automation package.

The gas cleaning system is highly important in coating lines, not only for reasons of environmental protection. It also has a strong influence on the energy efficiency of the furnace. SMS Siemag thus pursues the strategy of designing the gas cleaning system such that the volatile paint constituents contained in the exhaust gas are returned to the combustion process. The know-how here lies in the design of the flow conducting system (Fig. 4). The heat in the exhaust air is used for burning the paint constituents in the gas. This is so favourable that under certain preconditions the plant does not need to have any external gas fed to it, since it attains an autothermic operating condition that naturally reduces the energy consumption to a considerable degree and at the same time ensures high cleanliness values in the exhaust air. The hydrocarbon content thus lies below 10 mg/Nm$^3$. For carbon monoxide and nitrogen oxides, the value in each case is less than 50 mg/Nm$^3$. This argument has, for example, opened the Chinese market for coating lines to SMS Siemag.

HEAT TREATMENT FOR HEAVY PLATE
SMS is working on model building, e.g. for the development of metallurgical and flatness models. Here, Drever can draw upon its own experience from plants already built. Within the company an intensive dialog is taking place between Furnace Technology and the rolling mill construction departments in order to offer the customer a fully integrated process.

With regard to the heat treatment of heavy plate, the corporate objective is to introduce a flexible process that can be easily controlled and reproduced with a view to replacing the current practice of achieving a rapid and high cooling rate for the formation of a purely martensitic microstructure by introducing the largest possible quantities of water over a short stretch of only around 3 m in a process that is difficult to control. As is the case with strip processing lines, this flexible process should enable given material properties to be attained precisely. The solution aimed at is inherent in the overall process, i.e. it comprises the rolling process, the heating and the cooling within an integrated procedure.

SMS Siemag is currently executing a demanding order for the heat treatment of heavy plate made of special steel for the Swedish works of Outokumpu Stainless AB. The remarkable feature here is that the annealing does not take place as usual in a roller-hearth furnace but in four large batch-type furnaces arranged in parallel. One furnace unit is constituted in each case by two chambers which are separate and thus able to be heated differently. The plates, of length up to 16 m, are fed in and discharged via a roller table which is situated in front of the chambers and which finally conveys the plates into a common quench.
The advantage of this arrangement is to be found in the enormous flexibility allowed by the possibility of simultaneous individual heat treatment of single plates in very small batch sizes. The lower space requirement in comparison with a roller-hearth furnace was likewise an important decision-making criterion in favour of this furnace plant.

For the Furnace Technology Division, this is the first integrated heat treatment facility for heavy plate to be designed, built and supplied under the division’s leadership and responsibility. All of these plants are designed and constructed according to a uniform standard specified by the customer. Particularly for the water supply and treatment system, there is no longer any need for the “take-over points” which formerly had to be specified between the supplier and the customer, because what the customer is now buying is a cooling rate that determines the material properties, i.e. an integrated process. This integration is further emphasized by the fact that the electrical and automation package, likewise supplied by SMS Siemag, also incorporates a cold plate leveller that has already been supplied.

**CSP Facilities of the Latest Generation**

SMS Siemag developed the CSP process 22 years ago and, with more than 28 plants supplied worldwide so far, has enabled an economically and technologically significant alternative to the traditional hot strip production method to assert itself on the market and then become the leader on that market. Even if the investment boom of earlier years has diminished somewhat recently, the demand not only for new plants but also for modernization of the initial facilities nevertheless continues to be so high that the company is able to invest in the further development of the process. This is true also for the roller-hearth tunnel furnace, which performs an important role in the temperature control between the casting machine and the rolling mill. These furnaces have until now been supplied by an external firm of furnace builders. In the future, they will be an important product of the firm’s own Furnace Technology Division in cooperation with SMS Elotherm.

The development of its own furnace in interaction with the casting machine and the rolling mill allows the company to envisage a new CSP concept as an answer to today’s more stringent market requirements, relating of course to energy consumption. Irrespective of whether electrical power or gas energy is utilized, the decisive factor is always the kWh consumed per ton of steel produced. This means that for SMS Siemag the CSP discussion has acquired a new dynamism.

**Author**

Thilo Sagermann
SMS Siemag AG
Düsseldorf, Germany
Tel.: +49 (0) 211 / 8814449
thilo.sagermann@sms-siemag.com