BINE Informationsdienst

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Efficient heating optimises industrial production processes

- **New processes offer the opportunity of optimising energy requirements, operation workflows and product quality all in one**
- **Research is focused on complete process chains and linking different processes**
- **Up to 40% energy savings possible**
- **Research institutes support information exchange between companies and industries**

Fig. 1

A generator shaft for a power plant leaves the reheating furnace of a hammer forge.

Several industrial products have to go through fire during production. In the metalworking industry, in the production of glass, ceramics and building materials as well as in parts of the food industry, heating processes are key production steps. About 65% of the industry's final energy requirement is expended on it. In Germany, industry furnaces are chiefly produced by small and medium-sized companies and close to every second furnace is exported.

Successfully introducing new and energy-efficient heating processes to operating practices is not all that easy. An innovative process is expected not only to reduce the energy requirement and the costs, but also to lead to an optimisation of product quality, production processes and furnace throughput as well as to flexibility vis-à-vis customer wishes and changed technical parameters.

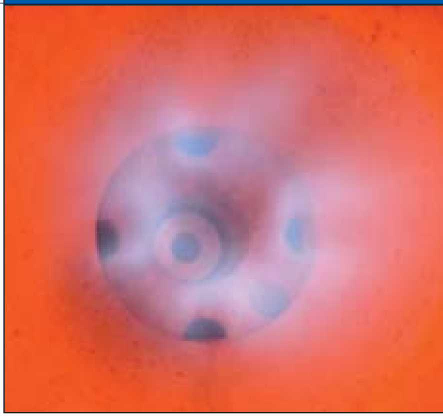
In the metalworking industry for instance, material characteristics of high-grade products in particular depend on e.g. precise heating, cooling and hardening processes, an exactly defined furnace atmosphere and equal heating of the entire material used. Today, an increase in efficiency is less likely to come from improved individual processes, which previous innovations have already perfected to the limit of what is physically possible, but rather from an optimisation of entire process chains, the linking of processes and a holistic approach to optimising the established production processes. At the centre of this development are e.g. more and more powerful simulation tools as well as model and rule-based furnace operation.

Each new plant offers the possibility of reducing the future energy consumption in the industry and improving the competitiveness. Many medium-sized furnace manufacturers and operators need support in order to stay up to date with current expertise and develop and introduce innovative processes. The research projects sponsored by the German Federal Ministry of Economics and Technology aim not only at developing more efficient processes but also supporting information exchange within and across the industries.

▶ Industrial heating processes

Heating processes are decisive for the quality, costs, energy requirement and environmental impact of many products manufactured in the steel industry. Heating, hot forming and heat treatment are often coupled. Since the smallest variation in temperature, combustion gas composition, furnace atmosphere or other parameters may have great effect on the product quality, these processes have to be understood, optimised and precisely controlled. The objectives are to develop an accelerated and equally convective heat influx to the entire material used, optimised exposure and loading times for the furnaces and a reduction of unwanted physical and chemical processes such as negative effects of scale, surface decarburisation and tension.
With regard to these objectives, several different approaches lend themselves to optimised heating processes: avoiding heat losses and recovering heat, exactly controlling the combustion gas composition, oxygen level and furnace atmosphere as well as linking individual measures to primary process management (e.g. model-based furnace operation). More and more powerful simulation programs and new sensors further contribute towards reproducing and understanding very complex furnace processes.

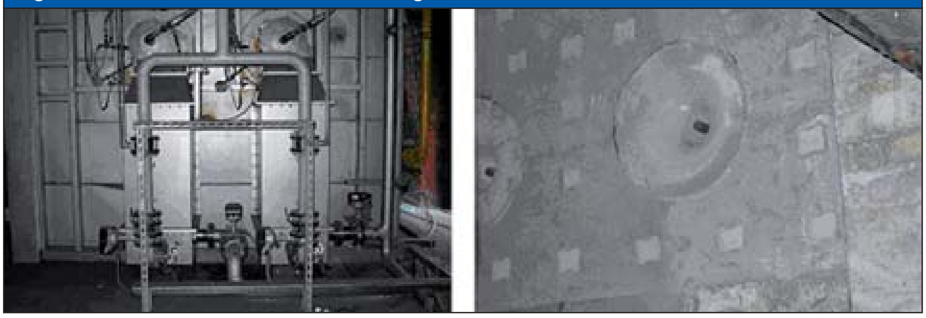
Fig. 2: Burner in operation



▶ New processes and instruments

For years, the German Institute for Applied Research and Development (Betriebsforschungsinstitut, BFI) in Düsseldorf has been dedicated to researching and developing efficient processes, instruments and concepts for the metal and metalworking industry and its heating processes. Descriptions of six promising developments are outlined below.

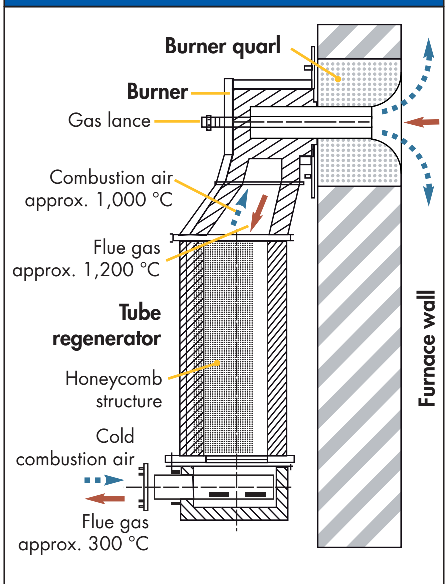
Fig. 3: Flat-flame burner with thermal regenerator



■ Burner and heating systems for multivalent use

A new flat flame burner has been developed for heating high-grade materials used which is also suited for the highest preheating of combustion air. The current operational test runs (**Fig. 3**) confirm that the pressure loss is very low, below 30 mbar, at a combustion air preheating temperature of 1,000 °C. The simple construction with combustion air flowing in tangentially allows for cost-effective production and little wear and tear. The Permanent Impulse (PI) process improves productivity by means of injecting combustion gases. The convective heat transfer on the surface of the material used is increased considerably due to the high burner impulse and high flow rate. This shortens the heating duration of the material used, allowing for the furnace to be loaded at shorter intervals. The PI process is currently being tested at an annealing furnace for ring heating.

Fig. 4: ROREBS on a reheating furnace



■ Heat recovery with thermal regenerators

As for heat recovery in high-temperature industrial furnaces, several new processes have been developed and put to operational use. The new systems have a very low pressure loss and are non-sensitive to accumulation of dirt.
The rotating regenerator burner system (DREBS) was developed to achieve continuous pre-heating of the combustion air. A rotating regenerator is based on a rotating thermal mass, around which hot exhaust gas is flowing on the one side and cold combustion air in counter flow on the other side. The use of this technology at a rolling mill furnace led to energy savings of 30–40% compared to the original recuperator operation. At several heating stands for heating steel works ladles, the saving was about 40%. The temperature evenness has also improved.
The latest new development is a compact pipe regenerator burner system (ROREBS) (**Fig. 4**). The freely adjustable cycle times between 10 seconds and 1 minute of the individual ROREBS make it possible to define the time and place of heating. This helped reduce the fuel requirement of a forge by approx. 30% compared to the original recuperator operation.

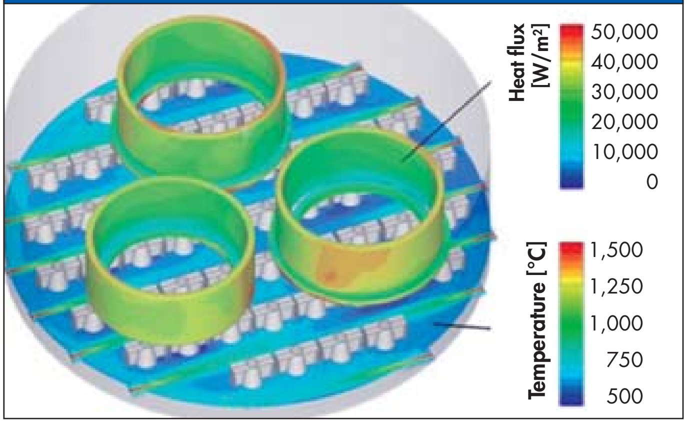
■ Atmosphere control guarantees product quality

In galvanising plants, reheating furnaces are generally operated with a large combustion gas surplus in order to avoid surface oxidation. This leads to unnecessarily high energy costs and CO_2 emissions. Finding solutions to this problem is the goal of a joint project. The modules included in this project are: an innovative furnace operation concept with new burn-off measurement system, new substoichiometric burner and more cost-effective conveyor rollers. At present, the development has reached the following state:

- The burn-off measurement system for determining the substoichiometric partial burn-off has been modified and tested successfully in operation with a target measurement accuracy of more than 99% (**Fig. 5**).
- On the basis of operational data and measurements, the energy and material flow balances for the preheating furnace of a galvanising plant could be determined with a balance error smaller than 0.3%.

Fig. 5: New measurement system for furnace atmospheres

Fig. 6: Improved heating of the material used by increasing the burner impulse



Simulation models for design and optimisation (CFD, Comsol)

It is possible to increase the convective heat influx selectively via the flow control and furnace atmosphere. This mostly occurs by increasing the average flow rate. Installing circulation blowers to this end, which have high material quality requirements, was often not economically feasible. In a newly developed process, the impulse flows of the combustion gases, injected directly into the furnace through the burner, are the single driving force of the atmosphere circulation. To achieve a targeted increase in impulse flows, two new heating processes were developed.

These developments were based on studies of combustion technology, flow conditions and heat transfer with the aid of numerical simulation calculations (Fig. 6) and technical laboratory trials. This new development can help improve the efficiency of several heating processes.

It is important to know the details of the properties of the materials used during the heating and heat treatment in order to attain the required product quality and energy efficiency. As a rule, however, these types of measurements cannot be conducted during the process. A newly developed FEM simulation model is able to detail the temperature, the thermal, elastic, plastic, transformation based and transformation induced plastic strain and stress states as well as the diffusion-controlled or non-diffusion phase transformation of the material used throughout all steps of the heating and heat treatment process. The simulation model is currently being used for developing, designing and optimising a new combined plant presently under construction. This plant consists of cooling sections, continuous furnace and hardening basin for heat treatment of seamless rolled rings straight from the rolling heat. The fuel savings per tonne heat treated material is expected to be approx. 18 Nm^3 of natural gas, leading to a reduction in CO_2 emissions of approx. 33.3 kg. At a planned material throughput of approx. 26,500 tonnes of the material used annually, this corresponds to annual savings of about 477,000 Nm^3 of natural gas and a reduction in CO_2 emissions of 882 tonnes per year. Another present application utilises the simulation model to optimise the austenitisation of forging ingots in batch furnaces with respect to furnace operation method and furnace loading. This minimises the tension and increases the energy efficiency during heating and transition of the forging ingots (Fig. 7).

Batch furnace model

Based on simulation calculations, the batch furnace model can optimise furnace cycles according to exposure time and energy input. This type of model can be used offline as an educational and/or planning system as well as online for process monitoring and drawing time purposes. This enables the development of optimal heating curves and furnace utilisation. Thus, it is possible to improve the operational planning and increase the throughput. The system is completely implemented within the ORACLE database and has a pleasant graphical user interface.

Model-based furnace operation

The model-based furnace operation has a wide range of applications, even for operators of small-scale plants. The different goals of the optimisation process can be defined, e.g. minimised energy use, equal through-heating or reduction of scale and tension effects. This relieves the operating personnel of carrying out routine tasks and makes possible optimum furnace operation even under irregular process conditions. The most significant improvements compared to “manual” operation are the automated process control adjustment to variations in the process gas supply or different material flows as well as the reaction to interruptions in the production process. The resulting cost savings and quality improvements soon lead to economic advantages. Several system operators have already put this furnace control system to successful use.

The process and systems knowledge, which in part has been accumulated over decades, is often entirely in the hands of a few highly qualified employees. Rule-based systems can be a means of saving and finding regular use of this store of knowledge. These systems can be used to control, document and optimise processes. In some applications, rule-based systems are given precedence

Fig. 7: Calculated temperature distribution (left) and tension distribution (right) in heating/austenitisation of forging ingots

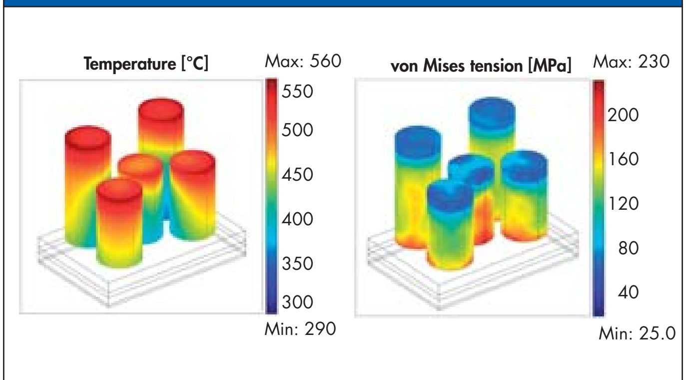
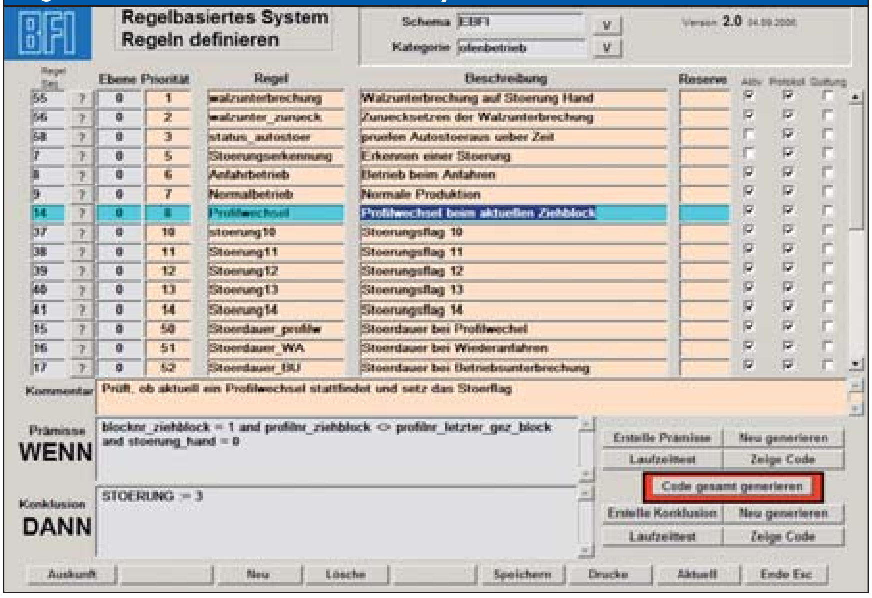


Fig. 8: Through-heating measurement with trial ingot

Fig. 9: User screen of the rule-based system



over model-based systems. This applies in particular if it is difficult to depict process control requirements analytically or if they cannot be depicted at all. At present, this solution is used in furnace operation systems and sintering plants.

▶ Conclusion and prospects

The energy efficiency of the German metal industry has increased significantly in the last years and the possibilities are far from being exhausted. Developing more efficient heating processes ready for the market is of prime importance.
The ROREBS process is expected to be introduced on the market soon. Increasingly powerful simulation tools provide new possibilities of optimising processes from the beginning. The burners are to be regarded as a link in the process chain. There will never be an ideal heating plant since it must always be adapted to meet the continuously changing product requirements.
Furnace technology will continue to be an important field of research in the coming years together with the integration of the material used. In addition, new designs and construction methods for strategic furnace types may offer interesting opportunities. As for heat recovery, further improvements and electricity generation in special power plants are possible. In the end, the industry has to be motivated, too, so that the efforts of introducing new processes pay off despite harsh, global competition and a booming steel industry.

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▶ ADDITIONAL INFORMATION

Literature (in German)
- Federal Ministry of Economics and Technology (BMWi), Berlin (Hrsg.): Klimaschutz und Energieeffizienz. Nov. 2008. Vertrieb: www.bmwi.bund.de (→ Service/Publications)

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