Flat flame burners for bogie hearth furnace

Heating of forging ingots in bogie hearth furnaces can be greatly improved by a specially designed ceramic nozzle burner that distributes heat in a more uniform pattern while minimising scale formation, energy consumption and NOx emissions, and maximising productivity.

AUTHORS: Uwe Bonnet, Hans Kaczor and Joachim Georg Wünning
WS Wärmeprozesstechnik GmbH and Buderus Edelstahlwerke AG

The special steelworks of Buderus Edelstahlwerke AG produces hot and cold rolled strip, rolled semi-products and pieces for die casting and free forging, with an annual production of about 85,000t. The forging blocks are reheated in gas-fired automated car bottom or bogie furnaces. The maximum length of the piece to be forged in the car bottom furnace is 15m. Forgings can then be annealed, tempered and shaped by a variety of CNC machines. The production portfolio of free forged pieces encompasses worked pieces for general machinery, energy generating equipment and small forgings. The largest weight is about 80t.

INITIAL SITUATION

Car bottom furnaces are designed for the heat treatment of particularly large pieces. The furnace at issue is approximately 10m long and 4.5m wide and was equipped with 18 high velocity re-circulating burners rated 250kW each, corresponding to a nominal, natural gas maximum throughput of 450Nm^3/h. Both side walls were equipped with nine such burners firing straight, hard jet flames. The cars are loaded apart, pushed into position and then sealing between the furnace bottom and the car bottom is automatically provided. The flame and the hot combustion gases were driven through the bottom car and the forging pieces as far as the opposite wall, from where they were forced upwards to the roof, eventually being re-entrained by the original jet issuing from the burner (see *Figure 1*). Because of this design, the pieces to be reheated for forging could not just lie on the bottom car, but had to be positioned in an accurate pattern on heavy steel supports measuring 400x400mm. The latter had to be put in exactly the right position in advance of loading otherwise the flame would directly impinge on the stock surface, causing additional oxidation and interrupting the heat distribution pattern. In these faulty passageways, because of the flame deflection, the supports and the stock would be locally overheated and the process of reheating the whole stock would be interrupted or take longer. Furthermore, the tips of the involved burners could be damaged by excessive overheating. The maximum total fuel throughput was 210Nm^3/h natural gas and was limited by the time interval required by the on–off control technique whereby every 60 seconds the burners of one side wall were interchanged with those of the opposite wall, so that only 50% of the installed 18 burners were available at any time. The furnace was divided into three zones and air preheating and low-NOx techniques were not adopted.

This was unsatisfactory in terms of productivity, maintenance, environmental pollution and overall cost. WS Wärmeprozesstechnik was given the contract to remedy this situation by revamping the furnace.

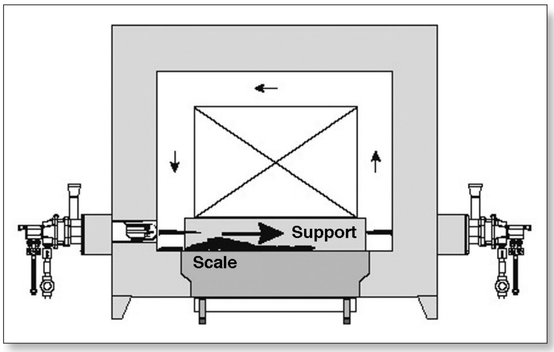

Fig.1 **Cross-section of the bogie hearth furnace**

FLAT FLAME REKUMAT® BURNERS

Figure 2 shows the scheme after revamping. Nine Rekumat burners, each rated at 180kW and provided with integrated air preheaters, were installed in the same longitudinal positions as the original burners on each side wall, but placed centrally. The total maximum gas flow after revamping was 315Nm^3/h with all 18 burners firing, distributed in three zones and fired in a circular pattern. Thanks to the increased overall power input, faster reheating of the stock could be achieved and a greater furnace capacity realised, as well as higher temperature reheat cycles. The new flat flame burners are ▷

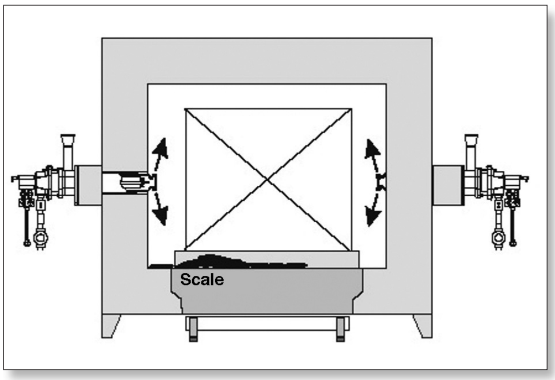

Fig.2 Cross-section through the revamped furnace

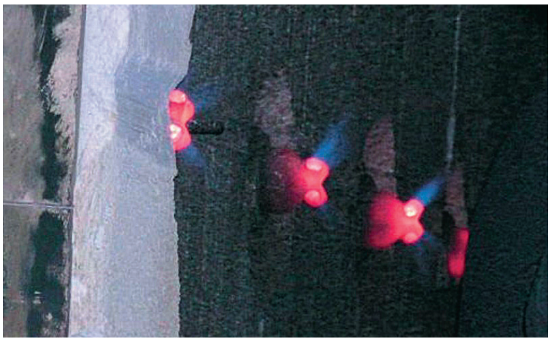

Fig.3 Flat flame burners in the forge furnace

further away from the bottom edge of the car and, as can be seen in *Figure 3*, the heat flow is no longer directed against the stock but, because of the arrangement of the burner nozzles, uniformly spread through the furnace. In *Figure 3* the flat flame burners are firing in flame mode and the distribution in side firing jet flames is clearly visible. *Figure 4* gives a detailed view of the burner nozzle installed in the middle of the furnace wall lagged with ceramic fibres. As the flame is no longer directed under the stock, the steel supports could also be substantially smaller (by a factor of almost 4). This provides a faster and more economic reheating process thanks to the reduced ballast to be reheated with the stock.

FLAMELESS FIRING IN HIGH TEMPERATURE FURNACES

The present developments of burners and heating systems focus on reduction of flue gas losses and noxious emissions. In particular for high-temperature processes the well-known technique of air preheating is used. The relevant energy saving potential is, however, only partially exploited. One important reason is the increase in flame temperature which produces excessive thermal NO formation. However, it may be possible to reduce the flame temperature and therefore the NOx emission by inertisation of the flame. The process relies on the principle of mixing large quantities of flue gases into the combustion air before the reaction with fuel takes place. The entrainment of the inert flue gases (that act as chemical and thermal ballast) is carried out by means of the high momentum of the air jets injected into the combustion space. Thanks to a special design of the FLOX® burner nozzles, controlled and completely flameless combustion takes place without pulsations or visible flames, and without the typical flame noise. In order to carry out this process, the fuel is mixed with the combustion air in a place where the required premixing with flue gases has already taken place, but where there is still enough turbulent mixing energy left to fulfil the combustion reactions. This flameless combustion mode is only possible above the ignition temperature of the fuel (850°C). Because flameless combustion is not visible, a burner safety control such as an ionisation or a UV detector will not work, so a furnace temperature above 850°C is the only safety method available.

The burners described here are fitted to fire both in flame mode (which is also used for start-up from cold) and in FLOX mode. Switching is easy and no separate burners are required for the two firing modes below and above 850° C. When the furnace is heated above the FLOX threshold, flameless combustion occurs and noise is significantly reduced. Most importantly, the NOx emissions are drastically reduced to 10–20% of the value corresponding to flame mode, and the problem of increasing NO formation with increasing air preheating is solved. In a conventional system, NOx formation increases exponentially with temperature while it drops by almost one order of magnitude in flameless conditions. Here, virtually unlimited high temperature preheated air can be adopted with very significant energy saving and hence with significant economic advantages. ▷

Fig.4
Flat flame burner nozzle from inside the furnace

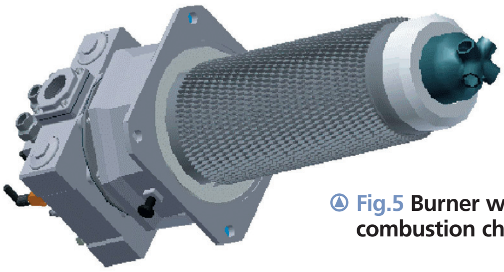

Fig.5 **Burner with pre-heater and combustion chamber**

Fig.6 **Flat flame burner in flame mode**

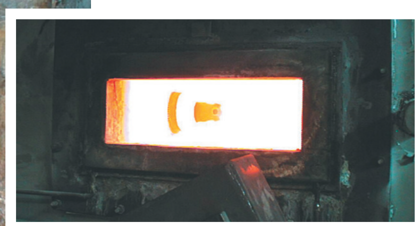

Fig.7 **Flat flame burner in flameless mode**

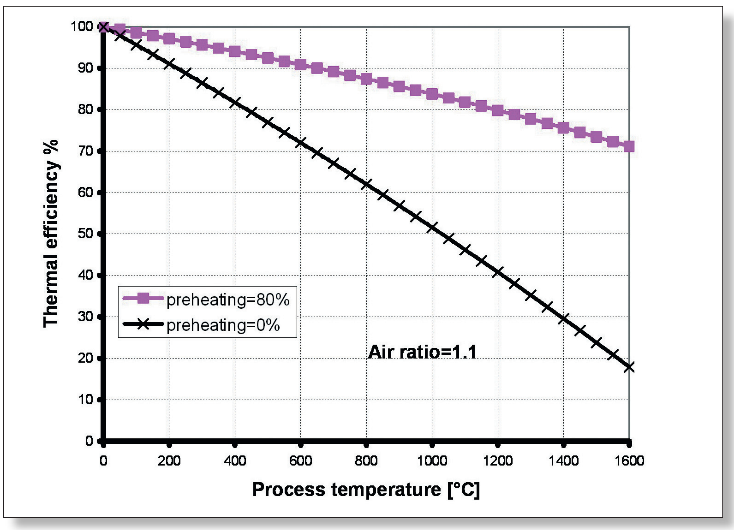

Fig.8 **Increase in thermal efficiency with air preheating**

To embody these results and to preheat air efficiently, self-recuperative burners are provided with an integrated air pre-heater shaped as a counter current corrugated heat exchanger (see *Figure 5*). A burner of the REKUMAT series with a specially designed primary combustion chamber was selected for the present case and produces either four axial flame or four flameless jets at 90° to the long axis of the burner. Every combustion air jet has such a high exit velocity that enough flue gases are entrained from within the furnace before the reaction with fuel takes place and a controlled flameless pattern is established.

The outlet momentum of the burner jets and the flow pattern so generated, produce a heat transfer to the forging stock and the furnace walls. The convective heat transfer to the wall zone adjacent to the burner overheats the wall and the latter is then capable of transferring energy by radiation to the stock. In contrast to the pre-existing solution, the use of flat flame burners no longer involves direct contact between flame and stock and so avoids local stock overheating. Furthermore, the temperature uniformity has been improved thanks to the division of the each flame into four jets. *Figures 6* and *7* were taken in a test furnace at the Gas Wärme Institute (Essen). In *Figure 6* the burner is in flame mode and in *Figure 7* is in flameless or FLOX mode. It is evident that the wall temperature close to the burner tip is overheated in flame mode (*Figure 6*) while a uniform temperature distribution can be inferred from *Figure 7*.

The expected reduction in specific gas consumption is within calculated limits (20–35%, depending on temperature), just comparing efficient air preheating with no preheating even without taking into account the reduction of the mass of the supports that carry the stock (see *Figure 8*). This expectation has been confirmed in practice. Furthermore, total available power has increased by a factor approaching two, allowing higher productivity and/or higher temperature cycles, which makes the furnace better available for high-performance operation.

CONCLUSIONS

The advantages of the flat flame burner applied to the forging furnace can be summarised as follows:

- An increase of more than 30% in the thermal efficiency without air preheat has been easily achieved
- Thermal NO formation is substantially abated even with very high air preheat
- The whole temperature span can be covered by a single burner in either flame or FLOX mode
- Troubles caused by oxidation and safety control can be minimised
- The four nozzle distribution heats the stock indirectly, so minimising oxidation
- The ceramic construction of the combustion chamber significantly reduces maintenance MS

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Hans Kaczor is head of the Energy and Control Department in the Buderus Edelstahlwerke, Wetzlar, Germany. Joachim Wünning is General Manager and Uwe Bonnet is in the Technical Office Nord/West of WS Wärmeprozesstechnik, GmbH, Renningen, Germany.