Direct firing of aluminium heat treatment systems

With the use of Kromschröder heating systems, it is possible to obtain combustion of a low polluting level even at system temperatures within the range of 200 °C to 700 °C. Thanks to the modular structure of the system, it is possible to adapt the required connection rating to suit the local conditions in place. Burner attachment tubes stabilise the flame. The protective flame tube within which the entire combustion process takes place prevents the flame from being cooled by the circulating atmosphere and the associated production of CO. In this way it is possible to exploit the advantages of direct heating.

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Introduction

Systems in the field of aluminium heat treatment are for the most part operated in a temperature range of between 200 °C – 700 °C. When heating using organic fuels – in this example natural gas – some special measures must be applied so as to ensure clean, complete combustion.

Using indirect heating systems, combustion can take place specifically within a defined combustion chamber, with the flue gases being channelled off directly. However, the disadvantage of these systems lies in the distinctly poorer level of efficiency, as a large proportion of the energy introduced is lost along with the flue gas.

Where the material to be treated is allowed to come into direct contact with the flue gas, direct heating is recommended, as here the entire energy flow is supplied to the system. As systems vary greatly in their construction, however, the heating system within the overall system must be adapted in each case. The following report demonstrates how this is possible using the modular Kromschröder system.

Influence of temperature ranges

For the field of industrial heating installations, **Fig. 1** presents four temperature ranges with an influence on the development of emissions and one temperature range with an influence on the application temperature for standard commercially available steels:

- 20 °C – 650 °C in relation to the production of CO,
- 20 °C – 1000 °C max. application temperature for heat-resistant steels,
- 650 °C – 1600 °C high reaction rate CO >> CO_2, low NO_x production,
- 1600 °C – 2350 °C in relation to the production of NO_x.

The maximum permissible application temperature for standard commercially available steels is also considered here, as in many cases heating installations take the form of lightweight constructions, and this means that the use of burner quarls is not possible. In all cases, it is necessary to adapt the heating system to the overall system, and for this reason the use of steel offering a high degree of heat resistance is called for.

As, for the most part, the heat treatment of aluminium takes place at a temperature of < 650° C, this report specifically addresses those relationships with a bearing on the avoidance of CO.

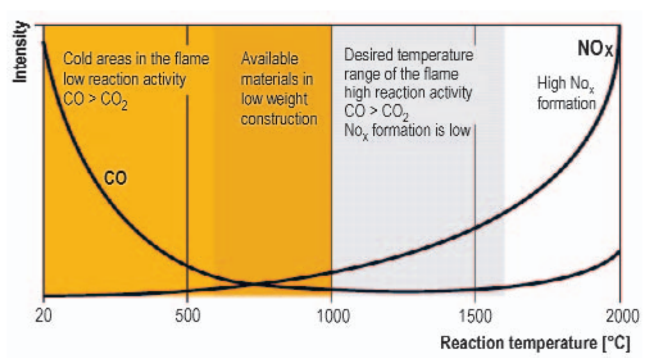

Fig. 1:
Available materials and the influence of the temperature on the development of flue gas emissions

CO reaction behaviour

In considering the combustion of methane, the following is a simplified representation:

$$CH_4 + 2\,O_2 \Rightarrow 2\,H_2O + CO_2$$

The production of the final products of water and carbon dioxide takes place over a number of intermediate stages. One of the crucial factors here is the secondary reaction from CO to CO_2:

$$CO + OH \Rightarrow CO_2 + H$$

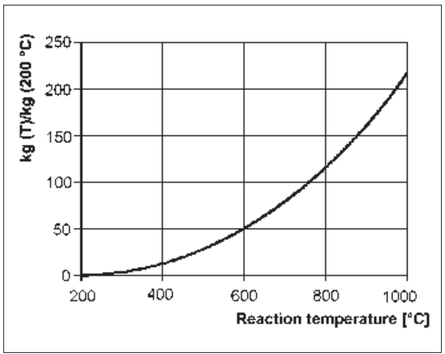

Fig. 2: CO reduction through oxidation with OH radicals as a function of temperature [1]

The reduction of CO through oxidation with OH radicals is extremely temperature-dependent. **Fig. 2** presents the reaction coefficient, standardised to 200 °C. While at a temperature of 200 °C the turnover of CO to CO_2 takes place comparatively slowly, at 600 °C the reaction turnover increases by a factor of 50. From a temperature of > 650 °C, it can be assumed that a reliable secondary reaction will take place.

Flame temperature

Fig. 3 shows the influence of the air-index (λ) and air preheat temperature on the adiabatic flame temperature of natural gas. The most economic combustion takes place at the near-stoichiometrical setting (λ = 1). For the curve with an air temperature of 25 °C, for the near-stoichiometrical setting (λ = 1) a theoretical flame temperature of 1920 °C can be read off. Practical measurements have demonstrated that because of the heat loss (non-adiabatic), flame temperatures can vary between 200 °C (burning in the open air with air excess) and 1600 °C (operation with quarl). Temperatures are significantly dependent on the setting and the ambient conditions.

Desired system temperature

The process or the furnace relining requires an adjustable temperature. For aluminium processing, these temperatures lie between 200 °C and 700 °C. If the representations above are applied, then for ideal combustion the temperature should be between 650 °C (secondary reaction temperature) and 1000 °C (max. temperature at which materials can be used). The task now is to ensure by means of the corresponding measures and installations that despite the lower system temperature in the vicinity of the burner or flame, the temperature still lies within the range of 650 °C to 1000 °C.

This applies in particular for the peripheral areas, as because of excessive temperatures here, the flame might destroy components, or if temperatures are too low the secondary reaction leading to CO_2 is interrupted.

In the core of the flame itself there are found distinctly higher temperatures, however where possible these should be kept below 1600 °C (increased NO_x production).

Below there are set out a number of applications showing how these requirements can be fulfilled.

Implementation and realisation

Burner selection

As has been described, the furnace temperature is a significant criterion for the selection of the mixer unit in the burner. At low ambient temperatures, as are commonly found in the heat treatment systems we are dealing with here, a burner head providing intensive mixing is selected, with a high degree of air twisting and a short flame (**Fig. 4**).

With the gas being injected radially and the intensive movement of air, the

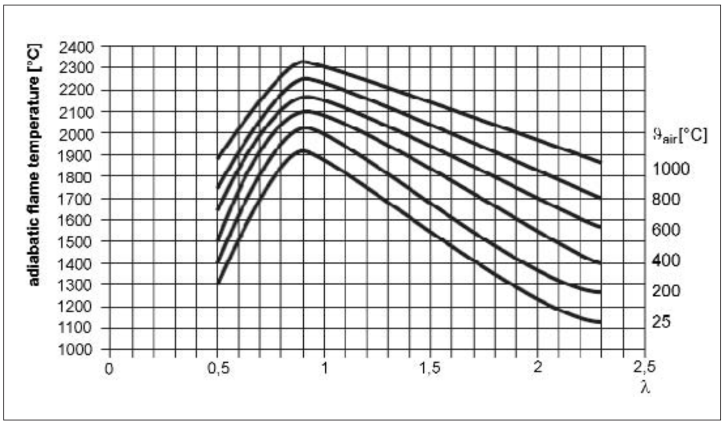

Fig. 3: Adiabatic flame temperature [2]

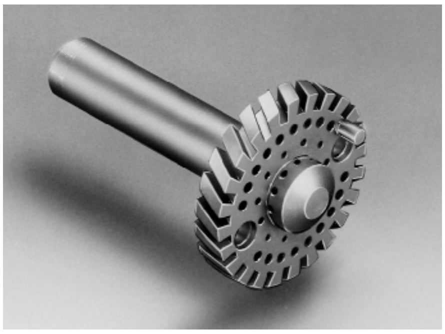

Fig. 4: Intensive mixing burner head

Fig. 5: Protection tube assembly

gas/air mixture is rapidly combusted. The selection of this mixer head therefore allows for the installation of a compact combustion chamber, taking due account of low-CO combustion at a low furnace temperature. The selected burner is the modular BIO burner. Its modular construction permits flexible adaptations in response to

- the type of gas,
- the installation situation,
- the burner capacity.

The burner is fitted with an attachment tube in heat-resistant steel. The burner is also surrounded by an additional pipe (the protective flame tube) in heat-resistant steel, to protect the flame from disturbing influences (e.g. cooling) caused by the furnace atmosphere flowing around it. This means that the flame is burning inside a "mini combustion chamber", as it were (**Fig. 5**).

The compact firing unit created in this way can be used in two tried-and-tested variants:

- *Flue gas exits through the combustion chamber open at the end.* This installation situation is preferred, for example, where the fan-driven furnace atmosphere is diverted from the horizontal to the vertical direction (**Fig. 6**).

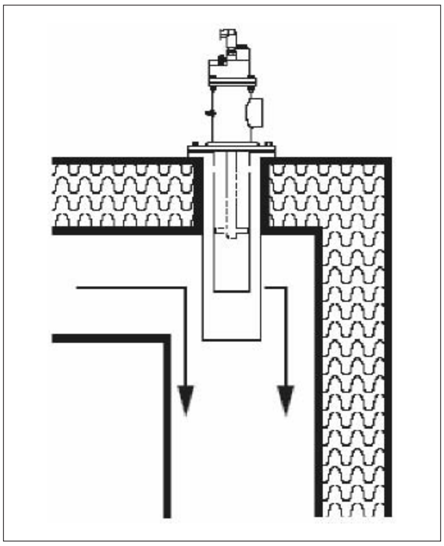

Fig. 6: Open end flame protection tube

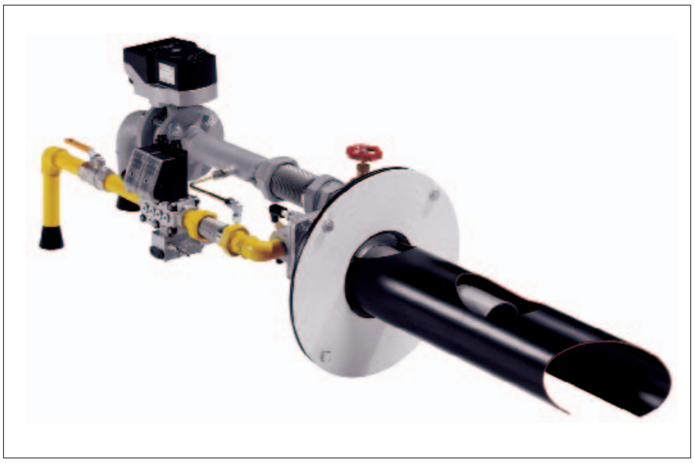

Fig. 8: Complete heating unit

- *Flue gas exits through the combustion chamber open at the side.* This variant guarantees complete flame combustion with the flow into the combustion chamber coming from the side. The side of the protective flame tube opposite the incoming flow side is provided with an oblong hole through which the flue gases reach the process (**Fig. 7**).

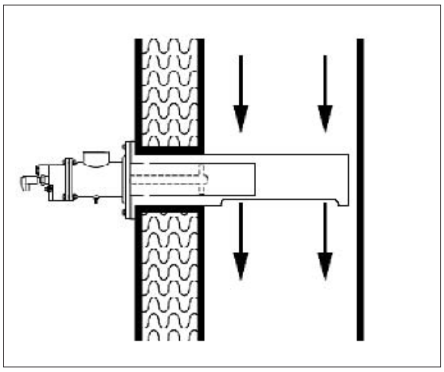

Fig. 7: Side-open flame protection tube

The burner capacity can be adapted to suit the relevant situation, and burner capacities of 40–1000 kW are available, depending on the requirements of the process. The length and diameter of the protective flame tube are adapted for the relevant installation situation. However, certain minimum lengths must be observed, as otherwise it is not possible to guarantee complete flame combustion, or the protective flame tube will be subjected to thermal overloading.

When operating the burner without protective flame tube, measuring burner flue gases, e.g. for setting a specific gas/air mixture, is practically impossible, as the burner flue gases are immediately mixed in with the furnace atmosphere. Accordingly, the protective flame tube can be fitted with a flue gas tapping point for measurement purposes, with this making it possible to measure burner emissions – without any influence being exerted by the furnace atmosphere.

From the tapping point on the protective flame tube there is a heavy-duty pipe connection led to the outer fastening flange. The test point at the outside of the flange can then be connected to a measuring device to provide a user-friendly solution.

Consequently, this type of influence-free flue gas measurement allows for reproducible burner settings.

Burner control

Keeping the gas/air mixture constant over the burner's entire control range is an important criterion for maintaining the desired flue gas values. Accordingly, the supplies of gas and air to the burner are pneumatically interconnected through the air/gas ratio control. This means that over the entire control range of the burner there is a constant gas/air mixture maintained. Even in the event of frequent or rapid changes in load, there is no change in the mixture set. Continuous control over the typical burner control range of 1:10 has proved its value in this type of application. The control range of 1:10 can be extended incrementally up to 1:650 through the use of a burner with an integrated low fire gas lance. The control function on the air side is fulfilled by the flexible actuator IC with the butterfly valve BVA. On the gas side, the compact and reliable Valvario series has proved an excellent solution for use as a solenoid valve (VAS) or air/gas ratio control (VAG) (**Fig. 8**).

Outlook

The combination of burner and protective flame tube has proved its value in many systems for the heat treatment of aluminium. With the flue gas tapping point inside the "mini combustion chamber", new horizons are opened up for the system operator in terms of burner settings. It is possible to proceed to apply a qualified burner setting with the effect of low-CO combustion, without disregarding the advantages of direct heating as discussed initially.

References

[1] Dr. von Gersum, Liere-Netheler: CO Bildung bei der Verbrennung von gasförmigen Kohlenwasserstoffen in Hochgeschwindigkeitsbrennern [CO Production in the Combustion of Gaseous Hydrocarbons in High-Velocity Burners]. Osnabrück 1998.

[2] Liere-Netheler: Pot Burners – Technology for the High-Temperature Zone of Tunnel Kiln Installations in the Ceramic Industry, Tile& Brick International, Vol. 12 No. 5 1996 425-431.