THE APPLICATION ASPECTS OF SELF-RECUPERATIVE AND SELF-REGENERATIVE BURNERS IN THERMAL DEVICES

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Abstract

The paper presents self-recuperative burners used in the modern metallurgical ladle drying from 10 to 60 Mg. The research of ladle heating cycle was carried out. The ladle of 25 and 30 Mg capacity was considered. The energy balance of a technological system with EPS-300, 300 kW burner was developed. Process of ladle heating rose from the temperature about 70 °C to the technological temperature 700 °C. The exhaust gas temperature, the surface lining temperature and the air preheat during the heating process, were determined. The heating cycle efficiency of around 40% was identified and proved to be much higher, when compared to its previous heating kind.

Research of the combustion process quality in the NO_x and CO concentrations was performed and compliance with the requirements of environmental emission limit was demonstrated as well. The increasing preheat temperature of about 300 °C and fuel saving was achieved by using the self-recuperative burner.

The self-regenerative burners are characterized by more preheat air temperature in comparison to the self-recuperative burners. This is the reason of using them in the high-temperature heating chambers. These burners, due to their specific actions, are characterized by a complex structure and require the use of custom control automatics. A compact regenerator is the basic construction element. Calculations of heating parameters apply to fast-changing transient states and therefore, the calculations are increasingly used computer simulations. An air heating temperature of around 1000 °C of the combustion chamber temperature about 1120 °C was achieved in the experimental research of the regenerator.

Key words

Self-recuperative burner, self-regenerative burner, ladle, regenerator, heating.

Introduction

The self-recuperative and regenerative burners enable, directly into the burner, the enthalpy recovery of exhaust flowing out from the working chambers furnaces. The integrated construction of self-recuperative and regenerative burners enables faster combustion air preheating, due to the location of the exchanger in the burner. The exhaust temperature losses often reach up to 200 K, at the central recuperate system, because of the exchanger location or poor insulation of the air distribution system. The integrated self-recuperative and regenerative burners system is characterized by lower temperature losses and lower air preheat. The lower combustion air temperature is due to the limitations of burner dimensions.

Industrial applications of self-recuperative burners

A rapid temperature increase of air combustion is obtained in the heat treatment furnaces when the self-recuperative burners are used. The self-recuperative burner EPR-300 is presented in Fig. 1. The EPR-300 burner power can be increased up to 600 kW for faster ladle heating of 100 Mg steel or for the large heat treatment furnaces. The construction of self-recuperative EPR-300 burner enables carrying out theheating of casting ladles up to 1200 °C. The EPR-300 burner parameters are as follows:

- range-variable power output: 150 and 300 kW,
- outflow substrates velocity: 60-100 $m.s^{-1}$,
- air temperature: the exhaust temperature function – up to 500 °C,
- air pressure: $\Delta p = 10$ kPa,
- gas fuel pressure: $\Delta p = 5$ kPa.

The EPR-300 burner is stable in a programmable range of 5-120 % of nominal heat power output. This burner is characterized by the rigid flame holding on uniform temperature distribution because of high outflow velocity of substrates (1), (2).

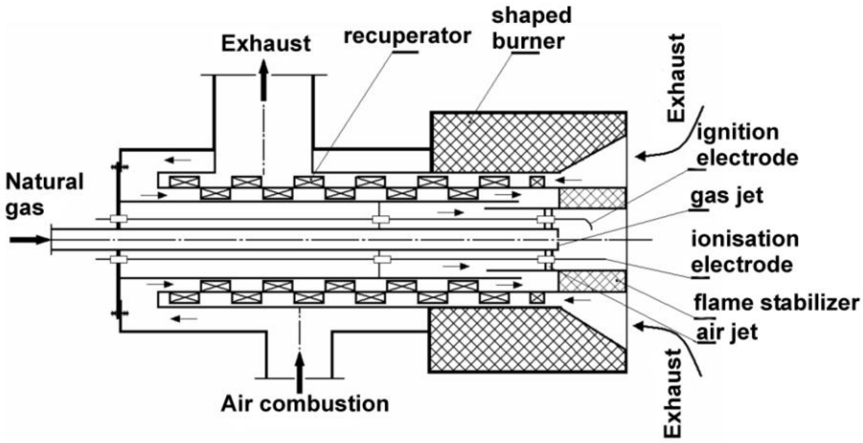

Fig. 1 *Scheme of EPR-300diffusive self-recuperative burner*

Application of self-recuperative burners in the heat treatment furnace

The heat treatment furnaces are characterized by high temporal variability of temperatures in the heating cycle, which often lasts for ten hours. The heating rate in the range of 15-200 $^{\circ}C.h^{-1}$ is applied in the heat treatment furnaces. Whereas the cooling rate can reach the value of 400 $^{\circ}C.h^{-1}$, the heat treatment process requirements usually enable on the temperature difference in the working chamber of $\Delta T \leq 10$ K. The heat-treatment furnace with car bottom hearth was considered. The 26 Mg charge was heated. Working chamber dimensions are: 2.5 x 2 x 10 m. The maximum furnace temperature is a function of the applied heat treatment type and way of maintenance. There were the 10 self-recuperative EPR-300 burners installed in the furnace (3). Creation of the interpenetrating exhaust recirculation zones is the result of alternate location of the burners. The low overpressure value in the working chamber was used to ensure technological requirements of the heating process. The quality combustion research was carried out during the high-temperature phase of the charge heat treatment. The furnace temperature was 1036 °C. The obtained results are as follows: NO_{xav}=185.16 ppm, CO_{av}=13.31 ppm.

Application of self-recuperative burners for drying and heating the metallurgical ladle

The metal temperature is a critical parameter in industrial processes on the surface of metallurgical furnaces. It is possible to decrease the metal temperature in the converter or electric furnace for the required process parameters if the optimal ladle preheating methods are used. For example, ladle lining temperature increasing from 1100 to 1200 °C is about twenty times cheaper than the steel overheating in the furnace from 1500 to 1520 ºC.
In drying and ladle heating methods applied till now:

- exhaust enthalpy of another source has been used,
- waste heat of hot ingots has been recovered,
- recuperate exhaust heat recovery has been used,
- system serial connection of two ladles has been used,
- process in which self-recuperative burner use has been carried out.

The last solution is only relatively effective. However, the substrates of low outflow velocity, from the burner and the burner outflow situated close to the ladle bottom, was the cause of local overheating. The heating process was corrected when the EPR-300 burner was applied. This burner is characterized by the large momentum of out flowing substrates and thus the burner outflow was situated in the ladle cover. The uniform temperature of ceramic lining was also achieved (1), (4). The low power range is used in the drying processes and for temperature stabilization for assumed level of the ladle lining heating. Meeting thermal requirements of the ladle lining drying process is particularly important for:

- safety casting process, i.e. avoid an explosion caused by moisture and the liquid metal contact,
- service life of the ladle.

The scheme of research station for drying and heating ladle is widely discussed in (1), whereas the burner installation scheme is presented in Fig.2. The ladles are heated in a horizontal position. This method allows the ladle heating range of the capacity 10-60 Mg steel. The front panel lining is made of fibrous material, which allows tight closure of the heating ladle. This is a necessary requirement of the optimization process, because the slight overpressure is maintained in the ladle during the heating process. The heating process takes place in two phases of the heating rate:

- up to 100 °C, heat-up rate $\leq$ 100 $K.h^{-1}$,
- over 100 °C, heat-up rate increasing up to 150-600 $K.h^{-1}$ (it depends on the ladle capacity).

The 25 Mg ladle was considered. The combustion process was characterized by the combustion air factor of λ = 1.03. The average value of carbon monoxide concentration of only 28 ppm was achieved. The value of NO_x for the same measurement conditions was very low and value of 38 ppm was noted. This is the mainly the result of intensive internal recirculation caused by out flowing streams substrates.

The uses of lower power self-recuperative burners of as high as 100 kW is acceptable in the case of smaller-capacity ladle heating <25 Mg steel and for a small chamber furnace. From the exploitation point of view, the numbers of burner switching “high power - low power” are therefore reduced.

The self-recuperative burner system of "high power - low power" is similar to that of “on-off” self-recuperative burner. The “on-off” system has the technological and ecological advantages (2), (5), (6), (7), (8), i.e.:

- for “high power on” option, the temperature profile is more equalized and there is no temperature peak in the flame. This is a requirement of technology and favours to decreased the concentration level of thermal nitrogen oxides,
- for “off” option, the temperature equalizes spontaneously of a ceramic lining ladle.

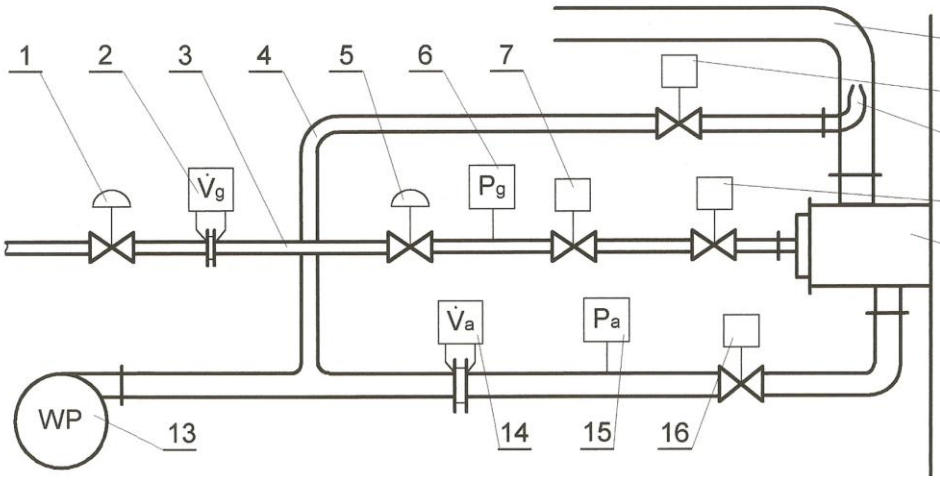

Fig. 2 *Burner installation scheme*

1-gas valve, 2-gas flowmeter, 3 gas pipeline, 4-air pipeline, 5-gas valve, 6-gas pressure sensor, 7-control gas electrovalve, 8- exhaust pipeline, 9- electrovalve, 10-injector, 11-cut-off gas electrovalve, 12-burner, 13-fan, 14-air flowmeter, 15-air pressure sensor, 16-control air electrovalve

Industrial applications of regenerative burners

The metallurgical industry commonly uses the heaters to preheat the air delivered to combustion process. The recuperative exchanger system is frequently used because of simple construction and lower costs comparing to others solutions. Generally, the air preheating of 300-500 °C is used. The value of 400 °C can be assumed as an average. The cases of preheated air temperature higher than 500 °C are also found, but they require special recuperative construction and materials, whereas this increases costs and does not necessarily have to be an economically attractive solution.

Another solution can be proposed for the high temperature heating furnaces – it is the regenerator system. This kind of exchanger is able to preheat the air to teh very high temperature - much higher compared to the recuperate (9). This solution, where the air preheating regenerator system is used, is called High Temperature Air Combustion (HTAC) or High Preheated Air Combustion (HPAC). The temperature of more than 1000 °C is obtainable with this system as indicated in some references (10), (11).

The HPAC technology has already been applied in different types of furnaces by means of different fuel types such as gas, oil and even coal and biomass. This new technology provides a most effective heat recovery, reduction of energy consumption, cleaner and cheaper production. A few cases can also be found in literature which proves that this system is characterized by lower investment costs compared to conventional ones (12), (13), (14). Possibilities which can be obtained if the high preheating system is installed are as follows:

- uniform the chamber temperature $T_{furnace}$-T_{air} < 100 K,
- effective heat flows increasing,

- energy savings: (40-60) %,
- installation size decreasing – about 30 %.

Regenerative burners in the high temperature pusher furnace

The 6 m heat-treatment pusher furnace was considered. The most important parameters were as follow:

- charging window dimension: 0.3 x 3 m - height and width,
- charge dimension: 0.25 x 2.5 m - diameter and width,
- fuel: industrial gas GZ50,
- process temperature: T = 1200 °C,
- combustion air factor: λ =1.05,
- productivity: $\dot{m}_{charge}$ = 10 Mg.h^{-1},
- furnace bottom overpressure: p_{fur} = 0 ÷ -1.8 Pa (optimal - depending on the air preheat),
- environment pressure and temperature: p_{env} = 100 kPa, T_{env} = 20 °C.

The pusher furnace was equipped with traditional gas burners. The preheat air temperature of about 350 °C was reached in central recuperate. The fuel consumption on the level 710 $m^3_N.h^{-1}$ was noted. After furnace modernization, a new preheating system, such as the regenerative burners, was installed. The combustion air preheats increased up to 1000 °C and the fuel consumption was decreased to about 495 $m^3_N.h^{-1}$. In this case, the fuel reduction reached as high as 215 $m^3_N.h^{-1}$ which represents about 30% less fuel consumption when compared to the case of 350 °C air preheating. It was the result of more efficient system of air heating which was installed. The furnace efficiency of up to 15 % was also increased. The average fuel price of 0.042 €.kWh^{-1} was assumed for savings calculations (15). The use of a new heating system resulted in financial savings of 2080, 62000 and 750000 € per one day, one month and one year (365 days) respectively. This case shows very significant profits, which could be achieved when the recovery system is improved, what is presented in Fig. 3.

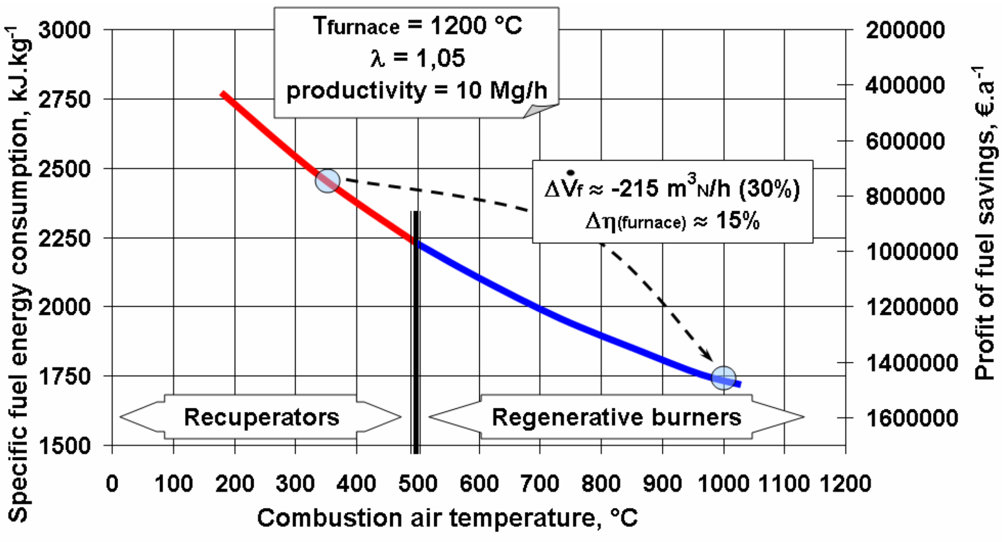

Fig. 3 *Profit of combustion air temperature increasing*

Conclusion

The self-recuperative EPR-300 burner was presented. The construction of self-recuperative burner EPR-300 enables carrying out of the heating of casting ladles up to 1200 °C. This burner is characterized by the rigid flame holding on uniform temperature distribution. Application of self-recuperative EPR-300 burner, in the heat treatment furnace, brought about the following results: NO_{xav}=185.16 ppm, CO_{av}=13.31 ppm.

The application of self-recuperative burners for drying and heating the metallurgical ladle was presented as well. In that case, the carbon monoxide concentration of 28 ppm and NO_x concentration of 38 ppm was reached.

The case of combustion air temperature increasing for the pusher furnace was also presented. Initially, the recuperative system was installed on this furnace. The air preheating of 350 °C was obtained. The combustion air temperature increased after changing the heating system. The recuperative burners were replaced by the regenerative burners and air preheating as high as 1000 °C was achieved. This investment resulted into the fuel consumption reduction (30%), furnace efficiency increasing (15%) and fuel savings profit of about €750000 per a year.

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