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Design Features of Air and Gas Double Preheating Regenerative Burner Reheating Furnace

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Abstract

Over the past decade, with the development of China's iron and steel industry, a lot of steel rolling reheating furnaces and heat treatment furnaces have been built, most of the furnaces adopt low calorific blast furnace gas and producer gas, and adopt regenerative burner. The air and gas double preheating regenerative burner firstly developed by Shenwu, China can preheat both air and gas to above 1000 °C, not only can increase the theoretical combustion temperature of low calorific value gas, but also can have higher heat recovery rate.

This paper introduces the design features of burner structure type, burner arrangement and installation mode, special furnace wall structure, combustion system, flue gas exhausting system, reversing and combustion control, combustion system safety measures, etc. of double preheating regenerative burner reheating furnace.

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1. Introduction

A large amount of BF gas is produced as by-product in the steel plants. Since its low calorific value is only 700 ~750 kcal/Nm³, it was not used as the single combustion fuel of rolling reheating furnaces and heat treatment furnaces in the past. The air and gas double preheating regenerative burner invented by Beijing Shenwu, is able to preheat both air and gas to more than 1000 °C, thus the theoretical combustion temperature of low calorific value gas can be greatly increased, such as the BF gas with calorific value of 750 kcal/Nm³, its theoretical combustion temperature can reach more than 2100 °C, completely meeting the temperature requirement of reheating furnace. The flue gas exhausted from regenerative burner has a temperature of only 150 ~180 °C, greatly saving the energy. The reheating furnace only using BF gas or other low calorific value gases can displace the coke oven gas for other uses with high added value.

During the decade of appearance of Shenwu's regenerative burner reheating furnace, with rare exceptions, almost all the rolling reheating furnace built in the steel plants, where BF gas is available, adopts only BF gas. The reheating furnace only use BF gas or producer gas with low calorific value can greatly reduce the fuel cost and make a significant contribution to the increase of economic benefit of steel plants.

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Based on the design and actual running of hundreds of reheating furnaces using double preheating regenerative burner, this technology is already mature after a decade of experience and improvement. Here is an introduction to the design features of double preheating regenerative burner reheating furnace.

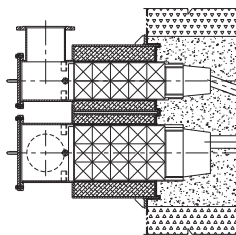
2. Structure of double preheating regenerative burner

Shenwu has designed the double preheating regenerative burner with a variety of structures, the common structural feature of them is composed of one air regenerative box and one gas regenerative box, both of which are filled with regenerators. The air and gas will meet each other and mix together to combust in the chamber, after being injected from the respective nozzle.

The features of double preheating regenerative burner:

- (1) The ceramic honeycombs, with a larger specific surface, are used as the regenerators, requiring a smaller structure size of burner that facilitates the installation and arrangement on furnace.
- (2) Since the burner's structure size is small and the high-temperature end cavity and nozzles are inset in the furnace wall, the burner's outline is compact and requires only a small space for installation.
- (3) The flow moves horizontally inside the regenerators, which are not easy to be blocked by dusts under the action of repeated blowing and reverse blowing.

The diagram and photo of double preheating regenerative burner structure are shown as figure 1.



(a)



(b)

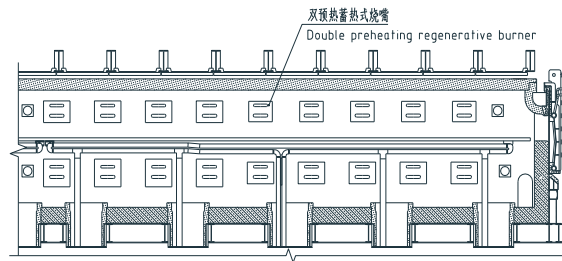


Figure 2 Arrangement of burners on furnace

Figure 1. (a) Diagram of double preheating regenerative burner (b) Photo of burner installation

3 Burner arrangement and furnace wall structure

3.1 Burner arrangement

The double preheating regenerative burners are installed in equal numbers on both side of the furnace, reversing regularly for combustion. The number of burners of each section along furnace length direction is determined as per the heating demand and the heating capacity of one double preheating regenerative burner is usually $100\sim 200 \times 104 \text{ kcal/h}$.

The burners are installed between the side upright columns of furnace steel structure, the nozzle of lower burners of the furnace chamber should avoid being straight to the water beam columns. The nozzle of upper burners should be 200~300mm higher than the billet upper surface.

An example for the burner arrangement in double preheating regenerative burner reheating furnace is shown as figure 2.

3.2 Furnace wall structure

The roof and hearth structure of double preheating regenerative burner reheating furnace is the same as that of conventional burner reheating furnace, only the furnace wall structure is different.

In double preheating regenerative burner, the high-temperature end cavity and nozzle form a unit, made of refractories, which is usually called burner brick, which is spliced together with the burner proper. The burner brick is inset in the furnace wall.

The furnace wall will have the following design features:

- (1) The thickness of furnace wall is around 500mm, almost the same as that of conventional reheating furnace.
- (2) The main material of furnace wall is refractory castable, which contains more than 60% Al_2O_3 and is especially favorable to the construction of the irregular structures. The casting work will be done in site.
- (3) The burner part inside furnace wall, together with the burner brick, should be completely filled with castables all around, so as to keep the burner sealed.

(4)The furnace wall, except the part around the burner, adopts a composite structure, which is composed of different materials in different layers, i.e. from inside to outside respectively castable(280~300mm), light weight clay brick, ceramic fiber board and ceramic fiber blanket. This composite furnace wall has a better thermal insulation property.

(5)The refractory castables are tightened on furnace wall steel plate by anchor bricks, which dotted the furnace wall surface with an interval of 400~500mm.

4 Design features of combustion system

4.1 Type and allocation of the reversing valve

The working mode of regenerative burner is a continuous cycle change from combustion state into exhausting state, then from exhausting state into combustion state. To realize such working state change, the reversing valve will be required. The special three-way reversing valve, invented by Shenwu, is quite suitable for using in the double preheating regenerative burner combustion system and will also facilitate the arrangement of the valves and piping system. The structure of three-way reversing valve is shown as the following figure 3.

There are two types of three-way reversing valve, small size and large size.

One double preheating regenerative burner requires two small size three-way reversing valves, which are to be installed close to the burner, one at the inlet pipeline of gas regenerative box and the other at the inlet pipeline of air regenerative box.

The large size three-way reversing valve is to be installed on the header of a group of regenerative burners, one on gas header and one on air header, used for the burners' centralized reversing control.



Figure 3 Three-way reversing valve

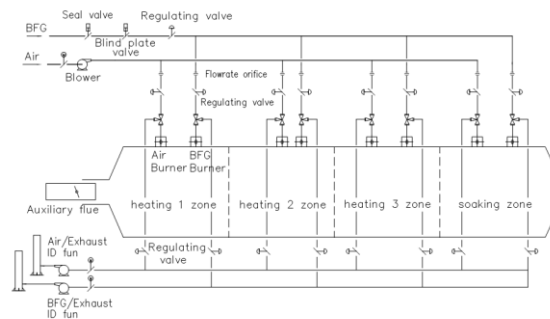


Figure 4 Demonstration for combustion system of double preheating regenerative burner reheating furnace

4.2 Gas and air piping system

The gas and air piping system of double preheating regenerative burner reheating furnace are equipped with a variety of valves for shut-off, adjustment and manual operation, as well as necessary measuring equipments for flows and pressures. The blower for supplying combustion air and the ID fan for extracting waste gases are also provided.

The combustion system of double preheating regenerative burner reheating furnace is shown as figure 4.

4.3 Flue gas exhausting system

The most special part of combustion system of double preheating regenerative burner reheating furnace is the flue gas exhausting system. The double preheating regenerative burner reheating furnace has two separate sets of system, gas-flue gas system and air-flue gas system, each of which is equipped with one set of ID fan and one chimney. The flue gas main pipe before ID fan is equipped with regulating valve for controlling the pressure of furnace chamber. If the ID fan adopts frequency conversion speed control, the flue gas main pipe could be mounted without regulating valve. The regulating valve should also be installed on the flue gas main pipe of each heating section, for regulating the flow distribution of flue gas, mainly on the basis of flue gas temperature.

5. Automatic control system

5.1 Reversing control

The PLC control system will do periodical reversing control on each reversing valve. The reversing cycle is adjustable and usually set as 1 minute.

There are many regenerative burners in the reheating furnace, if all burners reverse at the same time, it will cause a big fluctuation of furnace pressure and temperature, as well as that of gas and air system pressure. To minimize such fluctuation as far as possible, the progressive staggered reversing mode will be adopted.

When each burner is equipped with a small size reversing valve, the reversing can be done progressively and staggered on one pair of burners after another. For example, when the reversing of one pair of burners finished, make the next pair reverse after 3~5 seconds and the rest can be done in the same manner. In this case, the reversing will have a minimum effect on the operation condition.

5.2 Combustion control

The flow orifice plate and flow regulating valve are to be installed on the gas pipeline and air pipeline of each heating section.

The PLC control system will carry out automatic PID calculation after comparing the measured value of furnace temperature with the set value, and control the gas flow and air flow through regulating valves, so as to make the furnace temperature approach the set value.

The air-gas ratio is automatically controlled via dual-cross amplitude limit control mode.

5.3 Furnace pressure control

The furnace pressure is mainly controlled by the main flue gas regulating valve located before ID fan, but also can be controlled via the variable frequency speed regulating of ID fan. And the auxiliary flue damper located at the end of furnace will be used for auxiliary regulation if necessary.

6. Safety design for combustion system

In order to ensure the safety of the double preheating regenerative burner combustion system, some safety measures are taken in the design, mainly includes:

- (1) Two sets of flue gas piping system should be designed, so that the flue gas exhausted from air regenerative box and gas regenerative box can be discharged via respective piping system, ruling out the possibility of mixing of air with the remaining gas in gas regenerative box.
- (2) The gas main pipeline will be equipped with quick shut-off valve, for quickly shutting off the gas in case of an emergency.
- (3) Except for the shut-off valve, the gas main pipe will also be equipped with blind plate valve, so as to ensure that the gas can be absolutely cut off.
- (4) The gas can be urgently and automatically cut off in case of low gas pressure, low combustion air pressure, low compressed air pressure and power supply system failure.
- (5) The gas can be urgently and automatically cut off in case of blower failure and ID fan running failure.
- (6) The explosion-proof valve will be provided at the end of each air distribution pipe.
- (7) A complete purging and bleeding system will be provided to the gas piping system.
- (8) In the operation area around the furnace, a certain number of CO detectors will be installed, which will sound automatically an alarm when the CO concentration exceeds the specified allowable value.