Thermal Characteristics of Heating-furnace with Regenerative Burner

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Thermal Characteristics of Heating-furnace with Regenerative Burner

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Thermal characteristics between the heating-furnace with regenerative burner and the classical triple-fired continuous furnace by heat balance testing for two billet steel heating-furnace at the same billet steel heating have been analyzed. In addition, the operating principle, the thermal characteristics and the effect of energy saving for heating-furnace with regenerative burner are introduced.

Key Words : Heating-furnace, Heat Balance Testing, Regenerative Burner

1. Introduction

Heating-furnace with regenerative burner is a new technique developed in 1980's. With exacerbation of world's energy shortage, classical triple-fired continuous furnace was modified to heating-furnace with regenerative burner at many rolling mills in the world. The principal difference between the heating-furnace with regenerative burner and the classical triple-fired continuous furnace is combustion system. In the new heating-furnace, the gas burner of classical triple-fired continuous furnace is replaced with regenerative burner. The recovered waster heat by regenerator of burner is used to preheat combustion-supporting air and gas, to increase the temperature of combustion-supporting air and gas, to increase calorific effect of furnace and to save energy.

Based on the heat balance testing of heating-furnace, thermal characteristics and effect of energy saving are analyzed in emphases.

2. Introduction to Heating-furnace

2.1 Regenerator Burning System

The heating-furnace with regenerative burner is composed of furnace body, regenerator reversing burning system, air system, gas system, fume extractor, wasted heat recovery system, thermal measuring system and control system. The burner, heat exchanger, chimney flue and chimney of classical triple-fired continuous furnace are removed in the new heating-furnace with regenerative burner.

Air and gas can be preheated to 1000 ℃ or even higher when they enter left regenerator by reversing system for the heating-furnace with regenerative burner. Preheated air and gas enter hearth by nozzle to combustion and to produce high temperature flame to heating billet. At the moment, right regenerator is used as fume extractor, and high temperature flame enter into regenerator and is cooled down to 150 ℃ by heat accumulator. Then the flame cooled down is discharged from right regenerator as a fume extracto r.

After 2 or 3 minutes, right regenerator is used to combust and left regeneration to discharge flue by reverse operation, and a working period is fulfilled. After many cycles, the furnace addition billet can be heated.

2.2 Technical Parameters of Furnace

The technical parameters of furnace are shown in Table 1.

3. Results of Thermal Test

Table 2 and Table 3 show the results of thermal test between the Heating-Furnace with Regenerative Burner (HFRB) and the Classical Triple-Fired Continuous Furnace (CTFCF).

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Item	Technical parameters
Type	The heating-furnace with regenerative burner
Effective dimensions (mm×mm)	24620×4200
Rating ($T \cdot h^{-1}$)	60
Intensity of hearth ($kg/m^2 h$)	580
Cooling-down method	Evaporation cooling
fuel	Blast furnace gas
Air preheat temperature (℃)	>1000
Gas preheat temperature (℃)	>900
Type of steel	Carbon structural steel
Billet dimension (mm×mm×mm)	200×1250×1750
Inlet temperature (℃)	Room temperature
Tapping temperature (℃)	1250

Table 1 The technical parameters of furnace

Table 2 The results of heat balance test

Heat inputs			Heat outputs		
Item	Quantity of heat		Item	Quantity of heat	
	HFRB/CTFCF	HFRB/CTFCF		HFRB/CTFCF	HFRB/CTFCF
	$KJ/T\times10^3$	%		$KJ/T\times10^3$	%
Q_1 Chemical heat of gas combustion	2152/2387	96.7/96.7	Q'_1 Physical heat entrapped by billet	1158/824	52.0/33.4
Q_2 Heat of billet oxidation reaction	74/82	3.3/3.3	Q'_2 Physical heat entrapped by fume	334/514	15.0/20.8
			Q'_3 Heat by air leakage from furnace door	80/85	3.6/3.5
			Q'_4 Chemical Heat of incomplete combustion	128/494	5.7/20.0
			Q'_5 Radiation heat loss from furnace door	17/18	0.8/0.7
			Q'_6 Heat absorption of cooling water	342/358	15.4/14.5
			Q'_7 Surface heat transfer loss	155/160	7.0/6.5
			Q'_8 Other heat loss	12/15	0.5/0.6
Total	2226/2469	100/100	Total(sum)	2226/2469	100/100

Table 3 Thermal performance index

Performance index	Value
	HFRB / CTFCF
Furnace thermal efficiency (%)	52.0/33.4
Thermal efficiency of Regenerator (%) /Thermal efficiency of heat exchanger (%)	86.2/68.8
Thermal efficiency of chamber (%)	44.8/23.0
Actual output (T/h)	55/55
Specific heat consumption ($KJ/T\times10^3$)	2152/2387
Recycled heat ($KJ/T\times10^3$)	1919/1698
Heat-transfer intensity ($KJ/(m^2 h)\times10^3$)	1127/628
Intensity of hearth ($Kg/(m^2 h)$)	523/363

4. Discussions

4.1 The Higher Furnace Thermal Efficiency

The furnace thermal efficiency of heating-furnace with regenerative burner is 52.0%, and the thermal effi ciency of regenerator can reach 86.2%. It is because of the higher recovery rate of flue utilization when regenerative burner was adopted. The thermal efficiency of Regenerator is related to heat accumulator at some degree, and independent of the temperat ure of furnace, so the higher thermal efficiency depends on the performance of heat accumulator.

At the present time, the mesh and sphaeridia structure heat accumulator is extensively used. The higher specific area and the good heat conductivity of mesh st ructure heat accumulator made its thermal efficiency reach 90%-95%, maybe even higher. But it is difficult to manufacture and easy-to-block. Although the specific areas of sphaeridia structure heat accumulator is lower than that of the mesh structure heat accumulator, the radius is very small. This leads to the heat transfer radius small, heat resistance small, change and cleaning convenience. The thermal efficiency of sphaeridia structure heat accumulator can reach 80% -90%.

4.2 The Higher Preheat Temperature of Air and Gas

The waste heat is recovered maximum limit in the heating-furnace with regenerative burner, so the average preheat temperature for air and gas can reach to 1050 ℃ and 967℃ respectively, and the preheat temperature of fuel is greater than t hat of tradition he ating-furnace. The recycled heat 1919×103KJ/T is the 86.2% of the total heat in the test. The heat is adequately utilized and heat loss largely decreased, so the object of energy-saving and economic effects-increasing is realized.

The higher preheat temperature of air and gas can make the combustion reaction spontaneous occur. This strengthens the flame stability, improves the temperature uniformity, implements the diffusion combustion of low oxygen, and be beneficial to decrease su rface oxidization of billet. In addition, higher preheat temperature decrease the flue-gas temperature to 150℃ that helps to decrease the air pollution.

4.3 The Single Blast Furnace Gas can be used as Fuel

Because the lower blast furnace gas calorific value cannot reach the heat capacity which makes the furnace heating-up temperature cannot meet the requirement of billet heating-up, blast furnace gas cannot be adopted as fuel at the classical triple-fired continuous furnace solely. As a result, some abundance blast furnace gas is discharged to air by some iron and steel plant and leads to energy waste and environment pollution. But at heating-furnace with regenerative burner, the higher preheat temperature of fuel makes burning temperature of fuel increasing, so the single blast furnace gas can meet the requirement of billet heating-up and can make the temperature of furnace chamber reach 1400 ℃. Here the calorific value and burning degree of blast furnace gas equal to that of coke-oven gas or that of mixed gas, even above that of natural gas. Therefore this type furnace can adopt the single blast furnace gas as fuel and make the best of secondary energy of iron and steel plant, from which we can decrease energy waste and environment pollution and reduce the produc tion costs.

4.4 Furnace can be simplified

Because the higher preheat temperature of gas and combustion-supporting air make the higher burning temperature of fuel, which leads to good temperature uniformity and higher heat utilization, the long furnace chamber preheating section at classical triple-fired continuous furnace can be removed. Only bringing-up section and soaking zone are reserved in the new type heating furnace, which shortens the dimensions of heating furnace and simplify furnace body. In add ition, the heat exchanger, chimney flue, chimney and other equipment of classical triple-fired continuous furnace are also removed, which can make the layout simple and rational, and decrease the intensity of operation and maintenance.

5. Conclusions

(1) The advanced technology, good energy-saving, easy-to-operate and easy-to-maintain are the characteristics of heating-furnace with regenerative burner. So this new type heating furnace has extensive application.

(2) The higher heat utilization, the higher preheat temperature of fuel, the simple furnace body, the low cost of production and environment pollution are the advantages of heating-furnace with regenerative burner. In the test, the surface heat transfer and incomplete combustion loss are relatively bigger, which is mainly due to the many

exterior pipe, higher temperature and frequent reversing. The problems can be solved by both the thermal isolation wrapping furnace body and the control of heat supply system regulation.

References

[1] Wang Shoude: Shaanxi science and technology press. Xi'an of China, 182 (1995).

[2] Chen Hongfu: Metallurgy industry press. Beijing of China, 165 (1999).

[3] Hou Changlian, Hu Heping and Dong Weimin: Iron and Steel, 37-1, 65 (2002).

[4] Tang Xianjun, Guo Qiang and Liu Shaoshun: Metallurgical Equipment, 52-3, 44 (2002).

[5] Xie Jiasong: Steel rolling, 18-1, 63 (2001).

[6] Han Xinsheng, Huang Xinmiao and Lu Yongqing: Steel rolling, 19-4, 28 (2002).