DEVELOPMENT AND APPLICATION OF HIGH RADIATIVE COATING TECHNOLOGY IN BF HOT STOVE[1]

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Abstract

A new energy saving technology for BF was developed by increasing the radiative rate of the coating on the regenerative checker brick surface inside hot stove. The theoretic analyze and experimental results indicated that higher radiative rate coating will improve the capacity of heat regenerative and heat released to and from the brick by increasing the surface temperature of the brick which strengthening the radiative heat transfer between the flue gas and the brick as well as the conductive heat transfer inside the brick which results in the higher blast temperature and reducing the coke rate of the BF. In addition, the nano/micro coating materials filled the cavity on the surface of the brick which protects the brick and increases its service life. The following parameters of the brick are improved after coating: the volume density of the brick, the crushing strength, tensile strength and the softening temperature with loading. But the pore rate and the distortion rate are decreased after coating which are good for prolonging the service life of the brick.

Key words: BF hot stove; Regenerative checker brick; High radiative rate coating; High blast temperature; Energy-saving.

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1 INTRODUCTION

Steel industry is a energy intensive industry and iron making process in BF takes over 60% of the gross energy consumption in a steel company. High temperature blast has been used in BF since 1828 in America. The theoretic and experimental results indicated that higher blast temperature not only plays a specific role in reducing coke rate and increasing yield, but also increase the pulverized coal injection rate since higher temperature blast improving coal combustion efficiency. Higher radiative rate coating on the checker brick surface strengthen the heat transfer process which results in the higher blast temperature. In addition, the nano/micro coating materials filled the cavity on the brick surface which protects the brick and prolonging its service life. The following parameters of the brick are improved after coating: the volume density of the brick, the crushing strength, the tensile strength and the softening temperature with loading. But the pore rate and the distortion rate are decreased after coating which are good for prolonging the service life of the brick.

2 THE EFFECTS OF HIGH RADIATIVE COATING ON HEAT TRANSFER PROCESS

Generally, when the temperature is over 900 , heat radiation becomes the principal style (over 90%) in heat transfer process, which is 15 times to the convection heat transfer under the same temperature. Most of the higher temperature radiation energy concentrate in 1~5μm wave range. For example, 76% and 85% of the radiation energy concentrate in the wave range when the temperatures reach to 1000 and 1300 respectively. However, the radiative rate of common refractory is lower in the wave range, in contrast with the high radiative rate coating which is much better in the process of radiation heat transfer in 1~15μm wave range (see Fig.1).

The radiative rate of common refractory is 0.6~0.8 under room temperature (see fig.2).,The radiative rate decreases obviously with the temperature increase. But the radiative rate of the new high radiative rate coating is always keeps above 0.9. As a result of materials' absorptivity is equal to the radiative rate under same temperature based on the conventional heat transfer theory, the checker brick's absorptivity increases with its radiative rate. The common regenerative materials' radiative rate in hot stove is limited in 0.6~0.8, however, only 0.4~0.5 at high temperature. Because of the low heat exchange efficiency, a lot of heat losses with flue gas instead of absorbed by the regenerative material. Therefore, increasing the radiative rate will results in much improvement of heat absorptivity and heat release process in hot stove. Higher radiative rate coating will improve the radiative rate of the checker brick from 0.4~0.5 to over 0.9 which strengthening the radiative heat transfer between the flue gas and the surface of the brick as well as heat conduction inside the brick during combustion period and the capacity of heat release during blasting period.

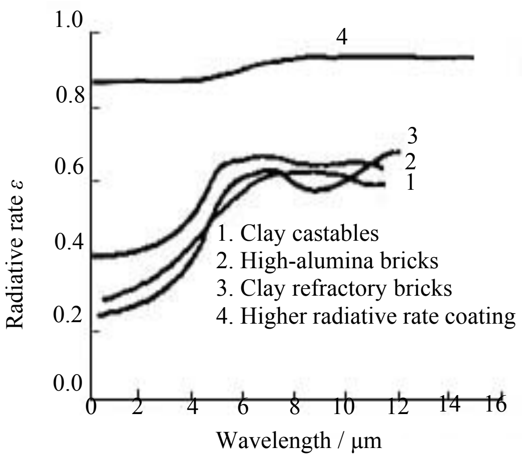

Figure 1. Spectrum radiative rates of diverse materials materials

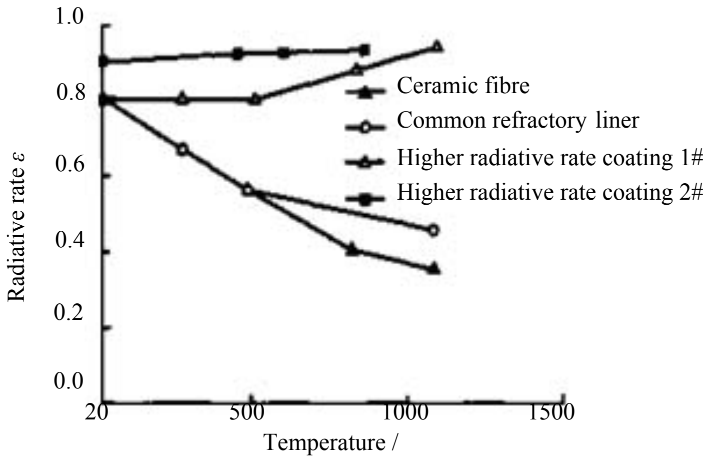

Figure 2 The effects of temperature on the radiative rate of materials

3 THE PREPARATION OF HIGH RADIATIVE RATE COATING

The materials used for high radiative rate coating is mainly made from sintering agent, suspending agent and adhesives etc. The first preparation is weighing the solid component according to the designed composition and then grind the mixture to micro-nano-size using superfine processing technology. Mix the micro-nano powder with adhesives and add the thermoplastic polymer and a small number of surfactant, finally use the equitment of high-speed mechanical agitation to make viscous fluid which is the high radiative coating product.

The processes for the coating preparation are as follows: cleaning dust for the checker brick→ spray adhesives→coating by soaking→ drying.

4 THE ADHESION OF THE COATING/REFRACTORY AND THEIR LITHOFACIES ANALYSIS

Heating the coated checker brick in the furnace to 1100   and water quenching repeatedly, the results showed that the coating material performed good adhesion with the brick and there is not any crack and shedding phenomenon happened. When the bricks were broken, but the coating was not shedding (Figure 3).

It could be seen that there is some change in color (Figure 4 and Figure 5), which shows the coating material has infiltrated into the brick(about 3 mm thickness (Figure 6).

Figure3 Results after thermal shocking for the coated sample

Figure 4. Structure of the coating infiltrated into the brick

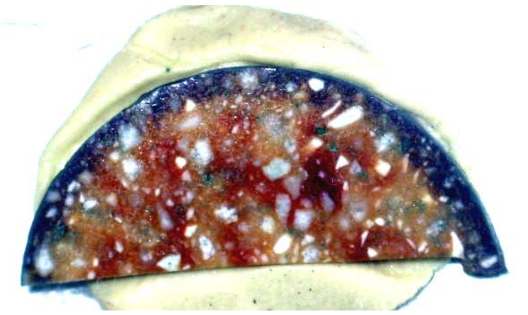

Figure 5 Structure of the sample after burning

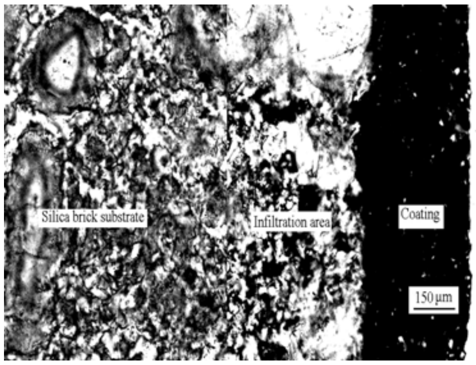

Figure 6 The coating microstructure

It could be seen from Figures 4, 5 and 6:

(1)The thickness of the coating is 0.29 mm, infiltrated depth is 2.96 mm.

(2)The interface between the coating and the brick has no crack, which shows shat the coating and the brick can be closely integrated together.

(3)The brick has many apertures which showed in white color in the figures; the small coating particles infiltrating into the matrix exist in the cracks of the bricks (the black material in the figures).

(4)The coating infiltrated into brick is an independent existence, and the composition of the brick does not react chemically with other substances or generate low melting phase.

5 THE EFFECTS OF THE COATING ON THE THERMAL PROPERTIES OF CHECKER BRICK

The experiment of heat absorption and heat-release rate for high-alumina and high-silica checker brick were conducted respectively under the same conditions and the two specimens with the same volume are from same checker brick, one of the specimen is covered with the coating whereas the other one is not. Both the heating speed and the cooling speed of the bricks with coating are faster than that of the uncoated specimen during the heating and cooling period. The specimen with coating has a higher capacity of heat regenerative than that of the uncoated one.

Heating and cooling curves of the specimens are shown in Figure 7. It can be clear seen that the temperature of the specimen with coating is higher than that of the uncoated one during the heating process, and the maximum temperature difference reaches to 283 , 13 minutes after the start of heating (the coated specimen reaches to 1142 ,whereas the uncoated specimen is only 1067). All the above data indicate that the coated specimen with higher heat absorption capability which can reach to the designed temperature in a shorter time, and the experiment indicates that the coating is good for heat absorption during combustion period in hot stove and result in reducing the heating time in the BF hot stove. The initial cooling temperature of the coated and uncoated specimen is 1142 and 1067 and the cooling time from the initial temperature to 390 is 6 minutes and 11minnutes respectively.

The thermal shocking experiment shows that the heat regenerative capacity are not changed for different material brick e.g.high-alumina anf silica checker brick under different conditions.

6 THE EFFECTS OF THE COATING ON THE PHYSICAL PROPERTY OF HIGH-ALUMINA AND HIGH-SILICA BRICK

Two specimens in which one is covered with coating and another one is uncoated, both of them are from same brick. The following parameters are tested respectively: volume density, the pore rate, the tensile strength, the break strength, the softening temperature with loading, and the distortion rate etc. The results are shown in Table 3, Table 4, Table 5.

Table 3. The performance comparison between coated and uncoated high-alumina checker brick

	Volume density (g/cm^3)	Pore rate (%)	The strength of compression resistance (MPa)	The break strength (MPa)	The distortion rate (%)
Before costing	2.43	25	49	5.8	-1.424
After coating	2.48	21	64	6.3	-0.623

Table 4. The high temperature physical properties contrast between coated and uncoated silica brick (1300 ×3h)

	Volume density(g/cm^3)	Pore rate (%)	The strength of compression resistance (MPa)	The break strength (MPa)	Linear change rate (%)
Before coating	1.80	19.88	28	12.23	+0.51
After coating	1.81	19.27	31	12.65	+0.33

Table 5. The softening temperature with loading and the distortion rate contrast between coated and uncoated silica brick

	Softening temperature with loading, (0.2MPa, 0.6%),	High temperature distortion rate (1430 ×50h), %
Before coating	1550	+0.405
After coating	>1650	-0.074

It can be seen from Table 3 to 5 that the volume density, the pore rate, the break strength and the strength of compression resistance of specimens with coating has slightly enhancement or almost the same as the uncoated specimens, the heat shock property are the same between the two specimens and the high temperature distortion rate of the high alumina brick with coating has greatly improved. The tables show that the coating is good for the brick.

The nano/micro meter size particle coating materials filled the cavity on the brick surface which decrease the pore rate and the volume density increases which is good for increasing the strength of compression resistance, the break strength and the distortion rate of the brick. All the properties improvement will prolonging the service life of BF hot stove.

7 THE NANO/MICRO COATING MATERIALS FILLED THE CAVITY ON THE BRICK SURFACE WHICH PROTECTS THE BRICK AND INCREASES ITS SERVICE LIFE

The nano/micro coating materials filled the cavity on the brick surface which protects the brick and increases the service life of the brick. Figure 8 shows the surface of siliceous brick before coating and Figure 9 showed it after coating with the same magnification. The figures indicate that the tightness and uniformity were better after coating than that before coating.

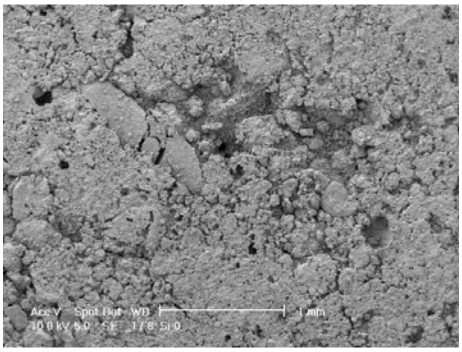

Fig.8 The surface of siliceous brick before coating (×25)

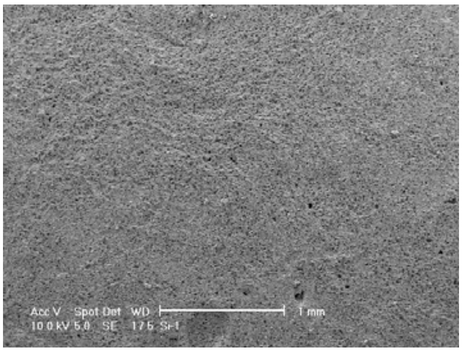

Fig.9 The coating surface of siliceous brick after coating (×25)

8 INDUSTRIAL APPLICATION CASES

The high radiative coating technology developed by Shandong Huiming Sci./Tech.Company which is first time to be used in hot stove in BF have been used in 59 hot stoves in Chinese Steel Companies and the blast temperature increased over 20°C due to the new coating material utilization which reduce coke rate, increase BF productivity and got huge economic benefit. Recently, more and more Chinese steel companies are going to adopt this coating technology.

8.1 Case 1

The No.2 hot stove of 1750 m^3 BF in a Chinese Steel Company was coated with high radiative rate material and the No.1 hot stove of the same BF was uncoated. Figure 9 and figure 10 showed the temperature before mixing in transition area of the brick. The figures showed that the heating-up rate was accelerated in combustion area and the rate reduced on air obviously after coating. The result was consistent with that of lab.

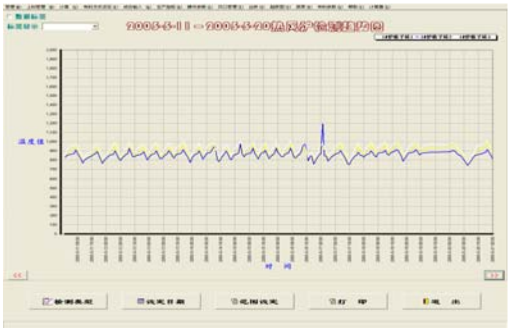

Figure 10 The temperature of the blast from No. 1 hot stove without coating

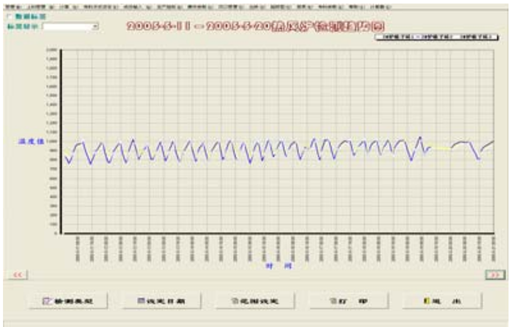

Figure 11 The temperature of the blast from No.2 hot stove with coating

8.2 Case 2

Another Chinese Steel Company built a 1080 m^3BF with 3 hot stoves in which No.1 and 2 stoves were coated with the higher radiactive rate material, and the No.3 stove was not coated. Figure 12 showed the temperature of the arch inside the hot stove, blast and waste gas in which the blast with coating was ~20 higher than that of uncoated one.

In addition, the temperature of flue gas is lower with coating than that of uncoated one which decrease the heat losses from hot stove and save energy by reduce coke rate, increase the productivity and increase the pulverized coal injection which reduce much pollutant from coking, sintering and iron making process.

Figure 12 Some temperature distribution in hot stove with and without coating in a Chinese Steel Co.

9 CONCLUSIONS

(1) Higher radiative rate coating will improve the capacity of heat regenerative and heat released to and from the checker brick by increasing the surface temperature of the brick which strengthening the radiative heat transfer between the flue gas and the brick as well as the conductive heat transfer inside the brick which results in the higher blast temperature.

(2) Higher radiative rate coating results in higher blast temperature which reduces coke rate and increases the productivity which save energy and benefit for decreasing pollutant from coke making, sintering and iron making processes.

(3) The following parameters of the checker brick are improved after coating: the volume density of the brick, the strength of compression resistance, the break strength and the softening temperature with loading. But the pore rate and the distortion rate are decreased after coating due to the nano/micro coating materials filled the cavity on the brick surface which are good for prolong the service life of the brick.

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