

Research on Preheating Pulverized Coal to Ameliorate the Blast Furnace Coal Injection

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Abstract: Pulverized coal injection of blast furnace is the important means of lowering ironmaking cost. It is a focus problem to improve the pulverized coal injection rate of blast furnace. However, improve the pulverized coal combustion rate has become a bottleneck of coal injection rate because of the contradiction between unburned pulverized coal and BF smooth operation. Basis of traditional technique, a new method by preheating pulverized coal to improve the pulverized coal combustion rate has been studied. Research shows that preheating pulverized coal can promote the pulverized coal combustion ratio, and reduce the heat loss of pulverized coal in BF through preheating pulverized coal.

Introduction

Since 1950, BF injection is suitable to the production in industrial scale. The technology of BF injection has rapid developed for more than half a century. Due to the coal resource is abundant in China, so the pulverized coal is the main injection fuel. After injection pulverized coal, the gas volume of furnace hearth was increased, the coke expense was reduced and the ore to coke ratio was increased. These changes worsened the penetrable quality of the charging column. Because of the disadvantageous influence of unburned pulverized coal, lead to further deterioration of the penetrable quality of the charging column. In addition, the pulverized coal which inject into furnace hearth will experience heating and decomposing process. These two processes are all endothermic process, but also the unburned pulverized coal takes away a part of physical heat. All these phenomena weaken the thermal benefit from pulverized coal combustion. Even lead to excessive injection quantity and exorbitant fuel ratio because of the decrease of replacement ratio, caused by economic irrationality. Therefore, improving the combustion of pulverized coal and thermal compensation, reducing the amount unburned pulverized coal became an urgent problem for pulverized coal injection technology.

The conventional methods of increasing pulverized coal injection rate and its limitations

The conventional methods of the increase of pulverized coal injection rate mainly includes coke quality improvement, raising blast temperature, oxygen-enriched blast, mixed injection, using combustion-supporting agent and so on. Although these methods have significant effect, these methods have certain limitations.

High quality coke is the foundation of pulverized coal injection. Improving coal quality could efficient improvement of coke ratio. High quality coke is high in price, if mass adoption of high quality coke will great reduction of economic benefit from pulverized coal injection.

Increasing air temperature can compensate for pulverized coal temperature, decomposition and absorption heat. Increasing air temperature promotes the coal cracking and burning. The production of improved air temperature is the effective technology of increasing coal injection ratio^[1]. But high blast temperature of hot blast stove structure, equipment and operating system requirements, increased hot air production cost.

Oxygen-enriched blast increases the oxygen concentration of hot air, increasing smelting intensity and improving the combustion temperature before tuyere, providing conditions for high pulverized coal rate injection. But, as rich oxygen rate rise, rising pulverized coal combustion rate downtrend^[2]. But also rich oxygen rate can easily cause partial oxygen concentration too high, existing explosive hidden danger.

Using mixed injection could promote pulverized coal combustion, playing respective advantages of two kinds of coal^[3]. But mixed injection could not breakthrough the limitation of the pulverized coal itself. The mutual promoted effects of the optimum proportion of two kinds of coal reach maximum. If we raise the coal injection rate further, we have to find other methods.

Combustion-supporting agent could improve pulverized coal combustion characteristics, having oxidation of combustion-supporting and catalytic cracking effects, decreasing the ignition temperature of pulverized coal, advancing burnout temperature, shortening the time of burnout temperature. Unfortunately, the effect of combustion-supporting agent is reduced without alkali metal^[4,5]. But also, the decomposed products of combustion-supporting agent, bringing a certain hidden danger. Moreover, the main main components of combustion-supporting agent are all noninflammable powder, having unfavorable action to improve the pulverized coal combustion rate.

Preheating of pulverized coal injection

Due to the decreasing coke ratio of pressure, Increased the amount of pulverized coal injection has become trends in modern iron making process. In process of pulverized coal injection, pulverized coal heating and cracking will consume part of the heat, causing raceway temperature decrease and theoretical combustion temperature reduces. As the amount of pulverized coal injection to increase, pulverized Coal absorbs the heat increased. Last solution is to raise hot air temperature, need large amounts of pulverized coal injection and high hot air temperature hard to get under the current situation this method there is insufficient. Moreover, traditional means of pulverized coal injection for improving has some limitations. It is therefore necessary to launch a new method to strengthen the capacity of the coal injection.

Nowadays, China pulverized coal injection temperature is around 80°C, preheating of coal powder injection coal powder preheating to 150~200°C and even more. Due to preheating pulverized coal temperature increase, the heat that consumption of pulverized coal in raceway lower, reducing cold pulverized coal on the cooling effect of hot air, speed up the pulverized coal combustion process, reduction of pulverized coal combustion time. Thus reduces the cooling effect of pulverized coal to hot air, accelerating the pulverized coal combustion process, reduction of pulverized coal combustion time. The pulverized coal in the limited time, space, temperature conditions increase the combustion rate as far as possible^[6]. In addition, because of preheating, coal surface occur a certain change in organizational structure. Because under the effects of the moisture and volatile emission and carbon heat expansion (before plastic deformation does not occur), surface fractal dimension of coal increased, this indicates that the surface porosity of pulverized coal increased. Porosity increases, pulverized coal and oxygen reaction area increasing. Thus, increased reactivity and is profitable for coal combustion.

Due to preheating of pulverized coal can be the good condition of pulverized coal combustion, coupled with the general method for improving pulverized coal combustion rate. If used in combination these processes are effective means of further increased the amount of pulverized coal injection.

Fractal analysis of preheating pulverized coal

Because of irregular particles of pulverized coal, pulverized coal particles surface and pores structure is complex. The classic method is very difficult to describe them. Through fractal surface of pores structure of pulverized coal can be explained.

According to MIAO, HU, WANG and others on the research^[7,8], fractal dimension of coal first increase and then decrease during the pyrolytic process. In the heating phase of the pulverized coal, as the moisture and volatile matter precipitation, coal particle surface produces a lot of micro-hole, pore structures become more complex, improving the coal particle surface fractal dimension.

According to the formula can calculate fractal dimension of pulverized coal particle. Fractal dimension of pulverized coal and its specific surface area and particle size are as follows:

$$\lg A = (D-3)\lg R \quad (1)$$

In the formula: A-the measured surface area of the pulverized coal, $\text{m}^2 \cdot \text{g}^{-1}$;

R-the measured particle size of the pulverized coal, mm;

D-Fractal dimension of pulverized coal.

According to Formula 1, In the case of pulverized coal particle size unchanged, after pulverized coal volatile precipitation form microporous on the surface of pulverized coal, these lead to the fractal dimension of pulverized coal particles increase. Thus, lead to increased coal particle specific surface area.

The results show that, large specific surface area coal ignition speed fast, ventilation condition good, but burnout time long. Especially in the late combustion, due to formation of unburned pulverized coal outside the thick ash layers, Oxygen is not easy to diffuse within, the central part coal is not easy to burnout. Casing ash residue content high carbon and declining combustion efficiency. The larger particle size is the longer burning time. Pulverized coal injection into blast furnace size is very small, and burn time is extremely short. So Oxygen diffuse to the internal difficulties of the problem will not be too evident in blast furnace coal injection process.

Summing up the above, preheating pulverized coal has a positive effect for pulverized coal combustion speed.

Through thermodynamics and dynamics to analysis of improving combustion rate by preheating pulverized coal

From thermodynamics, the most important balance is CO/CO_2 of the balance during pulverized coal combustion. It shows whether the burning is fully, reflects the level of combustion efficiency. At a relatively high temperature ($t > 1200^\circ\text{C}$), Combustion reaction as follows:



At this time, Because of the high temperature gasification of carbon surface had a strong gasification reaction:



As temperatures rise, Reaction of carbon surface speed up, producing more carbon monoxide. Pulverized coal burns more completely. In theory, CO/CO_2 during coal combustion is controlled by the following equation:

$$\text{CO}/\text{CO}_2 = 10^{3.4} e^{-12400/RT} \quad (4)$$

According to the formula (4), as the temperature rises, CO/CO₂ increasing. Preheating pulverized coal will bring a part of heat for blast furnace, rising the tuyeres temperature, making CO/CO₂ increase. Preheating pulverized coal is good for combustion from thermodynamics.

Pulverized coal of combustion process dynamics is a very complex. It includes homogeneous and non-homogeneous process. There are four main processes:

- 1) The oxidant in gas phase diffusion to the pulverized coal surface;
- 2) Devolatilization and diffusion of hydrocarbons in pulverized coal;
- 3) Chemical reaction;
- 4) Products transferred to the air.

Preheating coal could make volatile matter and hydrocarbons early release. This shortened the second process consumes time. So preheating pulverized coal can also promote pulverized coal combustion on the dynamics.

Some problems of preheating pulverized coal

Because preheating coal could make volatile matter and hydrocarbons early release. These gases are combustible gases. In other words, a part of effective combustion components will dissipate with preheating. This will cause a certain loss of fuel. But through technological methods could collect these combustible gases, and injecting into blast furnace with pulverized coal. Because the gas combustion conditions are obviously better than solid particles, Therefore, these escape of combustible gases are not wasted, but it will improve injection effects. In addition, because of preheating pulverized coal, Pulverized coal carrying physical heat will have a more significant increase. To security of coal pulverizing system can put forward higher requirements, needing to do a good job for explosion-proof measures.

Conclusions

In this article the following conclusions can be drawn:

- 1) Preheating pulverized coal injection can reduce the temperature drop due to heating up and cracking of pulverized coal enters furnace.
- 2) Through thermodynamics and dynamics analysis and discussing, we know that through preheating pulverized coal to increase pulverized coal combustion rate is feasible.
- 3) The dissipated volatile and combustion components because of preheating pulverized coal should be collected for injection fuel and this process have a certain security risk. So in production it is important to note security measures.

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