Sinter Quality Prediction Based on Parallel Genetic Algorithms

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Abstract: In the experiment of measuring assimilation and flowability of iron ore powder, different methods are used in this paper. This method takes into account the information of reaction process synthetically, that is, the evaluation index is defined based on multi-factor consideration, so the description of iron ore powder is more comprehensive. Although there are many methods to guide ore blending, the task of sintering cup experiment to verify the ore blending scheme is still very large. The method used in this paper to determine the assimilation and fluidity of iron ore powder can provide a preliminary prediction of the metallurgical properties of sinter and reduce some unnecessary sintering cup experiments and droplet experiments.

1. Introduction

High basicity sinter is always the main raw material for blast furnace ironmaking in China. Sinter production plays a decisive role in blast furnace ironmaking, regardless of burden composition, pig iron cost, waste discharge and environmental protection. The quality of sinter plays a key role in the production, energy consumption, pig iron quality and blast furnace life of blast furnace ironmaking. The quality of sinter consists of three parts: chemical property, physical property and metallurgical property. The relationship among them is that chemical property is the foundation, physical property is the guarantee and metallurgical property is the key.

2. Quantum Parallel Genetic Algorithms

Quantum parallel computing is the product of the combination of quantum parallel mechanics and computer science. It has the ability of quantum parallel superparallelism that classical algorithms do not have, and can accelerate some important classical algorithms. In the late 1990s, the emergence of Quantum Parallel Genetic Algorithms (QGA) attracted wide attention. A probabilistic optimization algorithm, which combines quantum parallel computing with genetic algorithm, uses quantum parallel bit coding to represent chromosome coding, updates quantum parallel revolving gates to complete evolutionary search, and uses quantum parallel theory. In this paper, we discuss the superposition, entanglement and interference of quantum parallel states. The concept of quantum parallel genetic algorithm was first put forward by Narayanan [5] et al. in 1996. The concept of Multi-universe in quantum parallel theory was introduced into genetic algorithm. However, the algorithm does not involve quantum parallel state, so it is not a real quantum parallel genetic algorithm strictly. Han [6] et al. introduced the concept of quantum parallel bits and quantum parallel revolving gates into genetic algorithm in 2002, and put forward a real quantum parallel genetic algorithm, which aroused the research upsurge of quantum parallel genetic algorithm. Compared with the traditional genetic algorithm, the advantage of QPAG is that QPAG replaces the conventional binary coding, improves the diversity of search solutions, has the characteristics of good population diversity, strong global search ability and fast convergence speed, and is suitable for solving combinatorial optimization problems [5]. However, the ability to solve the optimization of continuous functions, especially the optimization of multimodal functions, is poor, and it is easy to fall into premature maturity. Document [3] uses the strategy of phase comparison of quantum parallel bits to update quantum parallel gates and adjust search grids adaptively to adjust the quantum parallel genetic algorithm, and tests the classical continuous functions to obtain good optimization results. Document [4] introduces niche technology into quantum parallel genetic algorithm, and introduces a penalty function into fitness function. Overpenalty function is used to modify the fitness of individuals and improve the efficiency of the algorithm. Document[2] introduces the idea of Multi-population and uses K-means clustering algorithm to divide sub-populations. Multiple sub-populations evolve separately to ensure the diversity of the population. The information exchange between sub-populations through immigration operation reduces the probability of the algorithm falling into local optimum, and improves the convergence speed and prediction accuracy of the algorithm.

3. Sinter Metallurgical Properties

The metallurgical properties of sinter include 900 °C reduction (RI), 500 °C low-temperature reduction pulverization performance (RDI), load reduction softening performance (TBS, TBE, △TB) and droplet performance (TS, Td, △T, △Pm, S value), these properties reflect the conditions of the sinter in the blast furnace smelting process.

The state in which the iron-containing charge in the blast furnace exists can be divided into three types: a block shape, a softening state, and a molten drip shape. The resistance loss of the upper block of the blast furnace accounts for 15% of the total pressure loss of the blast furnace, and the resistance loss of the softening zone at the lower part of the furnace body and the waist of the furnace accounts for 25% of the total pressure loss, and the loss of resistance of the molten drop zone at the abdomen position of the furnace accounts for 60% of the total pressure loss of the blast furnace. Therefore, the main part affecting the blast furnace antegrade is the droplet drop belt in the lower part of the blast furnace. Because of this, the new concept of keeping the blast furnace stable and long-term is: the blast furnace operation is mainly to control the gas volume index of the lower bilge of the blast furnace, supplemented by the upper material feed operation of the blast furnace, and the gas distribution curve of the large platform plus the small funnel is formed.

The merit or deterioration of 900 °C not only affects the gas utilization rate of the upper part of the blast furnace, but also affects its reflow performance, that is, affects the gas permeability of the lower part of the blast furnace. Therefore, it is a basic metallurgical property, and to the sintergeneral alkalinity of 1.9, its RI value should be greater than 85%.

The low-temperature reduction pulverization performance at 500 °C is the low-temperature reduction strength of sinter in the blast furnace. It is the limiting link of the upper gas permeability of the blast furnace. The blast furnace melting requires RDI+3.15≥72%. If the chalking index is lower than 60%, it should be sprayed before entering the furnace. In the past, $CaCl_2$ was sprayed, but the danger of Cl entering the blast furnace was too great. Therefore, it is now possible to reduce the new environmentally friendly products without Cl to reduce RDI index.

Blast furnace smelting requires that the initial softening temperature (TBS) of the sinter is higher than 1050 ° C. The acid charge below 900 ° C is not conducive to the permeability of the softening zone in the middle of the blast furnace. The softening properties of sinter are often related to the mineral form of the flux. The silicate flux reduces the TBS value, while the carbonate flux helps to increase the TBS value of the sinter.

Droplet performance is one of the most important properties of sinter metallurgical performance, because the gas permeability resistance of the droplet belt accounts for more than 60% of the total resistance loss of the blast furnace. Therefore, attention should be paid to the improvement of the performance of the sinter droplets and the droplet properties of the sinter. It is related to the content of its grade, SiO_2, Al_2O_3, FeO, TiO_2 and so on. The droplet performance of high-grade, low slag, low Al_2O_3, low FeO sinter is better, and it is worse when reversing. Blast furnace ironmaking requires the S value of the integrated charge to be ≤ 40 (kPa ° C).

4. Determination of Carbon Content

In the droplet drop experiment, the main components of the slag phase are FeO, CaO and SiO_2 due to the reduction of CO. Assimilation performance and flow performance experiments without carbon, the main components of the slag phase are Fe_2O_3, Fe_3O_4, CaO and SiO_2. In order to accurately obtain the relationship between the basic characteristics of the sintering and the properties of the droplets, the assimilation performance, flow performance experiments and droplets are sought. The melt composition in the experiment was close, and coke powder was added to the cylindrical sample because C could promote the conversion of Fe3O4 and Fe2O3 to FeO or even Fe.

The oxygen content of iron oxides in the reduction process is a change from higher oxides to lower oxides:

when it is >570 ℃, $Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow Fe_xO(FeO) \rightarrow Fe$ (1)

When it is <570 ℃, $Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow Fe$ (2)

It is assumed that all the Fe elements in the cylindrical sample exist in the trivalent state, ie hematite. In this case, the maximum amount of coke powder is required to be converted into FeO. The reactive formula is

$$2C + O_2 = 2CO \quad (3)$$

$$Fe_2O_3 + CO = 2FeO + CO_2 \quad (4)$$

Direct reduction of C at room temperature ~1150 °C under nitrogen is difficult to occur. The reduction reaction of air C after 1150 °C is carried out according to formula (1), (3), (4), according to the weight and content of the cylindrical sample. When the percentage of coke is about 5.6%, the Fe element will be completely converted into FeO, considering the segregation and loss during the mixing. The experiment uses 6% carbon content. In the actual sinter process, the composition of iron minerals in the sintered product obtained from hematite powder varies with the carbon content. When the Fe element in the sintered ore is mainly stored in the form of FexO, the carbon content is 14-16% [5]. There is a large difference in carbon content between the two, which is due to the fact that the actual sintering production of carbon is mainly used as a heat source, and the experimental heat source is provided by the heating furnace, and the actual production of coke segregation is also large.

5. Analysis of Experimental Results

The results of the droplet test show that with the gradual increase of the proportion of the star powder, there is basically no major change in the melting temperature (TS), the total characteristic value (S), and the reflow temperature range (ΔT2), the maximum pressure difference (ΔPm) and the droplet performance shows an increasing trend. The reason may be that the content of FeO in Yixing powder and Baca powder is almost equal, and the melting start temperature (TS) depends on the melting point of FeO low melting point slag. At the same time, due to the high content of TiO2 in Yixing powder, under high temperature conditions the Gibbs free energy of TiO2 and CaO is much lower than the Gibbs free energy of Fe2O3 and CaO. Therefore, the reaction of TiO2 with CaO is more likely to cause less liquid phase [8], which causes the starting drip temperature (Td) rises and the maximum pressure difference (ΔPm) increases.

A very important property of the blast furnace hearth is its gas permeability, which determines the amount of gas passing through the charge. The soft melt zone determines the gas permeability of the blast furnace charge. The modern blast furnace ironmaking requires the sinter to have a high initial melting temperature. The interval is narrow and the maximum differential pressure during the droplet process is low [9]. Although there is no uniform standard for the droplet drop test, we found that when the comparison of the droplet data is relatively low (content <3%), the effect on the metallurgical properties of the sinter is acceptable. When the star powder is relatively high, the metallurgical properties of the sinter will be significantly deteriorated.

The comparison of the total characteristic value of the droplet performance with the melting characteristic parameter, FIG. 1 is a comparison result of the total characteristic value of the droplet performance and the characteristic number of the melting property.

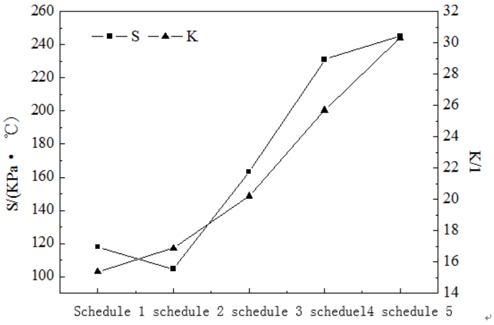

Fig.1. The comparison diagram of *K* and *S*

6. Conclusion

The number of melting performance characteristics proposed in this paper has similar meanings to the total characteristic value of the droplets. Therefore, the use of the number of melting characteristics to verify the sintering ore distribution scheme can provide further prediction for the quality of the sintered ore and improve the quality of the ore. Through calculation, the average ratio of S to R ratio of the five kinds of ore blending schemes is 3.26. Therefore, it is recommended that the melting property characteristic number of the sintered ore is R≤12.27 (for the blast furnace charge, the S value is ≤40 KPa·°C is suitable).

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