The Research Process on Converter Steelmaking Process by Using Limestone

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Abstract. Compared with traditional converter steelmaking process, steelmaking process with limestone uses limestone to replace lime partly. A lot of researchers have studied about the new steelmaking process. There are much related research about material balance calculation, the behaviour of limestone in the slag, limestone powder injection in converter and application of limestone in iron and steel enterprises. The results show that the surplus heat of converter can meet the need of the limestone calcination, and the new process can reduce the steelmaking process energy loss in the whole steelmaking process, reduce carbon dioxide emissions, and improve the quality of the gas.

1. Introduction

In recent years, with the rapid development of Chinese economy, the environmental protection is paid more and more the attention of the country. Iron and steel metallurgy industry has large energy consumption, and it is also one of the main industries of CO₂ emissions. Currently, lime is used as a kind of fluxes to put into converter in steelmaking process which is obtained in the lime kiln. After a period of time when the lime cooled, the lime can be transported normally and transported to steel mill for converter slag smelting. In the whole process, from lime kiln to the converter, the temperature should decrease to about 25 °C from more than 1000° C, but in the process of converter smelting, the temperature of lime need be raised from 25°C to more than 1000°C again[1-5]. Through the analysis of the whole process, the cooling heat dissipation of lime in the process is not effectively utilized, and this causes a great energy loss. In BOF steelmaking process, the main source of heat income is the physical heat and chemical heat from element oxidation, and in order to maintain the temperature of molten bath in the converter, scrap is often put into converter as a cooling agent. Considering that domestic scrap market would remain underdeveloped and inefficient state in a relatively long period of time, which has the following problems such as amount of scrap steel is insufficient, the price is high, and it is not beneficial to ensure smooth and stable operation in BOF furnace.

2. The History of the Steelmaking with the Limestone

At the earliest time, the limestone calcination technology was not fully developed, limestone was used to put into the converter as fluxes. Later, with the maturity and development of limestone calcination technology, active lime has completely replaced limestone and became one of the main flux in the converter. Due to the large specific surface area, high porosity, active lime can quickly be slagging and has better efficiency of dephosphorization. Therefore, a reasonable period of time in the future, limestone as fluxing agent could not be used in the converter. Especially under the guidance of "beneficiated burden materials policy and concentrate policy", one put more attention to study the
highly active lime production, failed to realize that irrationality of lime in steelmaking process from limestone kiln.

On November 14, 2016, the steel industry was adjusted and upgraded, and the planning which was issued by the ministry of industry and information technology of China (2016-2020), and it pointed out that because of the period of much serious challenges and valuable opportunities, iron and steel industry had to focus on 10 key tasks. Namely one should actively and prudently reduce capacity and leverage, improve the steel layout adjustment, improve the level of effective supply capacity for independent innovation, promote the iron and steel industry, develop intelligent manufacturing, promote green manufacturing, promote merger and reorganization, deepen open-door to the outside world, enhance the capacity of iron ore resources and create a fair competition environment. Thus, the iron and steel industry faces more serious challenge, and a new development of converter smelting process is imperative.

Using limestone instead of part of lime in the steelmaking process has the following advantages.

1. Decrease CO₂ emission which is from limestone calcination in the lime kiln; CO₂ has micro mixing effect, which helps to improve molten pool reaction condition; CO₂ can easily oxidize element in molten pool, reduce oxygen consumption, and improve the quality of converter gas.

2. Reduce cold iron material consumption, limestone decomposition is endothermal, which can result in the local low temperature, and this is advantageous to remove phosphorus fast.

3. The cost of using limestone is far lower than that of using the active lime, limestone can smelt and save cost.

3. The Application of Process Using Limestone in the Enterprises

3.1 The Advantages of Using Limestone

In recent years, considering that the iron and steel industry faces the rigorous situation of energy conservation and emission reduction and the huge pressure of cost savings, the process of using limestone instead of part of lime in converter steelmaking process has appeared in China[6-15]. Hangang, Laiwu, Baotou, Wuhan steel, Benxi steel, Chongqing steel, Liuzhou iron & steel group all have adopted the process. The Shouqin steel, Bayi iron and steel company and other steel enterprises also have chose the process to increase efficiency and saving energy and reduce consumption for the purpose of using the technology, and achieved success.

These iron and steel enterprises' practice shows that when limestone is used to replace part of lime, the heat balance of converter in the early stage and slagging effect can meet the requirement of steelmaking production; the process can reduce consumption of lime, at the same time it can reduce the consumption of cold iron material; CO₂ from limestone decomposition as a weak oxidant can easily oxidize element in the molten pool, and thus reduce the consumption of oxygen, improve the scrap of converter gas; ultimately reduce the steelmaking production cost, and achieve good economic benefit. The iron and steel enterprises usually require limestone particle size, particle size of 6-30 mm, the particle size which does not conform to the requirement of quality is less than 5%.

3.2 Theoretical Research of Using Limestone

(1) Research on material balance using limestone

The early research is focused on the converter steelmaking cost and income, and based on converter molten iron chemical heat in converter and physical heat, the material balance and heat balance of converter after limestone instead of lime was calculated. The results shows that the limestone can replace lime. Under the condition of the research, the largest limestone replacement ratio is about 70%. The process using limestone instead of part of lime can reduce scrap and oxygen consumption, and improve the quality of converter gas. If the largest limestone replacement ratio was used, CO₂ emissions can reduce to 29.96 kg per ton, the quality of the carbon monoxide increased 32.7 kg/ton, and the steelmaking cost saved 36.84 RMB/t[16].

(2) Research on the slagging of limestone
The study of steelmaking process using limestone was very little abroad, there was not foreign report about it in iron and steel enterprises. The limestone in the shape of 11 mm × 11 mm × 11 mm cubes decomposition behavior in converter slag was studied by using the tube high temperature furnace at 1600°C, the results shows that limestone decomposition produces dense layer, and the density of dicalcium silicate layer is not conducive to the slag, but limestone can be used as a coolant in converter. The melting behavior of cubes lime samples in the slag were studied, the results show that lime melting process can produce the density of dicalcium silicate on its outer layer, and the layer of material hinderes the further dissolution of lime\[17\].

(3) Research on powder injection in converter

The limestone decomposition behavior in molten iron at 1300°C was studied. The results show that there is a layer of white neat ring material on the cross section of the outside after the cylinder limestone sample decomposing, which is lime layer after limestone decomposition, and the inner gray part is not the uncalcined limestone. Using the image processing software, the decomposition layer thickness of 0.3 mm can be obtained\[18\].

Through the line scan, iron distribution is observed on the decomposition of limestone layer along the radial direction. The diffusion depth of iron was determined by surface scan, and the results show that the Fe can further spread to about 1200 microns. According to gibbs free energy calculation, CO\(_2\) from limestone decomposition can oxidize Fe and generate (FeO) (l), which can permeate along the calcined lime inside the pores in lime, and this is good for early rapid slagging of converter.

Considering that limestone decomposition in the molten iron decomposition pressure is greater than that in the lime kiln, the preliminary model controlled by pressure difference was established based on the CO\(_2\) flow driven. Through the preliminary experimental results, that CO\(_2\) flow is driven by pressure difference control for the limestone decomposition can be preliminarily determined.

The researcher further compared the top-blown converter powder injection via bottom lance and top lance, and the powder injection via bottom lance blowing focuses on its influence on particle penetration ratio and particle size distribution. The results show that the powder particles injection by bottom lance can gain greater particle penetration ratio than that by top lance, powder spraying conditions, and the gas via top lance is very abundant, so powder injection via top lance is superior to the bottom blowing powder spraying.

(4) Research on limestone decomposition

Wang from Northeastern university won the national natural science foundation funded project on the “surface of the limestone decomposition in the converter and slagging characteristics and its metallurgical behavior” research in 2013, which was mainly paid more attention, limestone decomposition behavior in the converter slag and slagging mechanism which the massive limestone was put into converter directly, but limestone decomposition and reaction mechanism in hot metal were not studied.

For massive limestone slag utilization ratio is not high and the speed of melting slag is slow, Zou put forward to improve the manner of addition limestone, which is injecting limestone into the molten iron by converter oxygen gun or side gun\[9\].

4. Summary

Anyhow, limestone instead of part of lime in the slag steelmaking process has been one of the most popular research fields in the iron and steel industry in recent years, the process for China's steel industry clean production, energy conservation and emissions reduction, and improvement of the economic benefit is of great importance. Although many researchers at home and abroad have made a lot of research on slag steelmaking process of limestone instead of part of lime, but mainly concentrated in the massive limestone in the study of the limestone decomposition in the converter slag. Predecessors generally have studied it based on material balance and heat balance, thermodynamics research, industrial test and limestone decomposition. Limestone in the decomposition behaviour of molten iron and its reaction mechanism has not been studied, limestone decomposition kinetics have not been established suitable for equation in the molten iron, limestone
decomposition reaction in molten iron has not yet been researched about restricted links and interface temperature of decomposition reaction which is changing with the hot metal temperature.

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