The Present Situation and Analysis of Slag Splashing Technology of Converter in China

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Abstract. Slag splashing technology is a common method to realize the long life of converter, which has the advantages of reducing the consumption of refractory, reducing the maintenance time of converter and improving the economic benefit. According to the technology of slag splashing in converter, the technical principle of slag splashing in converter and the existing problems of slag splashing in converter are summarized. By the parameters of slag composition, slag splashing gun location, slag basicity and slag retention being changed, the technology of slag splashing in converter was optimized.

1. Introduction
The age of converter has become a comprehensive technical index to measure the technical level and process operation of a steelmaking enterprise¹, which reflects the technical level and production management level of the steelmaking plant. Therefore, how to improve the furnace life of converter has been the goal pursued by scholars at home and abroad. Converter lining generally consists of working layer and permanent refractory layer. In the early 1990s, with the improvement of quality of magnesium-carbon bricks, the age of some large and medium-sized converters in China also increased significantly. A kind of advanced technology for improving the furnace life of converter with less investment and no special equipment is needed. However, the steel mills used in the process of technology also have various problems, which need to be further explored.

2. Technical principle of slag splashing furnace

2.1. Basic principle of slag splashing furnace
Furnace protection by slag splashing technology is based on the slag viscosity technology development. After the converter steel, a part of the final slag is left. Then, the modification agent is joined, the viscosity is adjusted, and the appropriate scope of composition of the slag is obtained. Those can make the MgO style and slag to produce chemical reaction to generate a series of high melting point material. Then the high pressure nitrogen is blown into the furnace with oxygen gun again, and this makes the refractoriness and erosion resistance of slag coating on the lining, and curing in the lining surface, forms high melting point solid solution to protect the lining of the technology of furnace protection.
2.2. Basic methods of slag splashing in the furnace
The slag splashing technology is to spray N2 gas through the top blow nozzle and hang the final slag of the converter on the wall of the furnace. Due to its simple operation, relatively small equipment investment and good slag hanging effect, it has been widely used at home and abroad in recent years.

2.3. Main process parameters of slag splashing furnace
The main process parameters of slag splashing furnace include: nitrogen pressure and flow rate, spray gun position; Furnace slag, molten steel temperature, slag melting temperature, overheating, viscosity and surface tension. The pressure and flow rate of nitrogen are the key factors influencing the slag splashing effect. The gun position control should be based on the fluidity of slag and the splash position. Generally speaking, the method of high front and low back can ensure the formation of slag and the effect of slag splashing, and prevent the bottom of furnace from rising. Slag splashing has great influence on the amount of slag splashing and is the most important parameter of slag splashing. In slag splashing, the amount of slag is not only an important technical parameter of slag protecting furnace, but also determines the thickness of slag splashing layer\[2\]. On the other hand, with the increase in the amount of slag left in the furnace, the slag's splash ability is enhanced, which is beneficial to the operation of slag splashing. Reasonable steel temperature and reasonable control of the converter slag are the keys to protect the slag splashing. High basicity, high MgO content and low FeO slag has high melting temperature and slag viscosity, which is conducive to slag splashing effect.

2.4. Slag splashing and furnace protection mechanism

2.4.1. Slag splashing layer melting phenomenon. The practice and research results show that the slag layer attached to the lining surface has uneven mineral composition. When the temperature rises, the low melting point in the slag splash layer first melts, separates itself from the high melting point, and moves slowly from the splash. The slag layer flows downward; The slag layer retained on the lining surface is high melting point mineral, which in turn improves the high temperature resistance of slag splashing layer. This phenomenon is the sub-melting of slag, also known as selective melting, which makes the MgO crystallization of slag splash layer and the high melting point minerals such as C2S gradually accumulate, improving the high temperature resistance of slag splash layer and protecting the furnace lining\[3, 4\].

2.4.2. Bonding mechanism between slag splashing layer and furnace lining brick. Slag splashing layer and magnesia carbon brick area can be divided into three parts horizontally\[4\]: slag splashing layer, adhesive layer and sintering layer. There are three ways of binding mainly through chemical bond, mechanical and chemical bond and condensation sintering.

2.4.3. Slag splashing layer protection lining mechanism. According to the analysis of the formation of the slagging layer by the phase structure of the slagging layer, it is concluded that the protective effect of the slagging layer on furnace village is as follows. After the splash, the slag sinks and fills the gap between the surface of the brick, or reacts with the surrounding MgO particles, or the sintering layer, to form a consolidated solid solution. Because of sintering layer, magnesite is no longer loose and lost, further corrosion of lining bricks can be prevented. Secondly, slag layer reduces the direct erosion damage of slag on the surface of lining brick. Finally, the new slag splashing layer can effectively protect the slag splashing layer interface between the furnace lining\[5\].

2.4.4. Corrosion loss mechanism of slag splashing layer. The slag splashing layer has good corrosion resistance to the slag of the converter. Due to the low basicity of the slag at the initial stage, the slag phase is mainly silica-calcium stone, while the slagging phase is mainly CS. Under high temperature, the two cannot coexist. The MgO and CS phases with high melting point were precipitated to
improve the melting point of slag splashing layer, which is conducive to resisting further erosion of slag[6].

3. Problems existing in slag splashing furnace process
(1) The lining of the furnace is difficult to control. After slag splashing, it is not easy to control the thickness of lining and irregular furnace body, which is not conducive to controlling slag and splashing and affects the further improvement of furnace age.

(2) The slag in the furnace should be cleaned before it is sprayed. However, in the slag splashing backward, there is steel in the slag. When slag is splashed to protect the furnace, the oxygen gun sticks to the steel. The mixture of molten steel and slag on the spray gun is difficult to clean. Problems in the process of steelmaking should be solved by controlling reasonable gun position and slag removal.

(3) The technology of slag splashing to protect the furnace is adopted, and the service rate of the converter is high and the deformation of the furnace shell is high. In the future, the leakage rate of the furnace and other equipment maintenance will further improve the inspection of the equipment and achieve institutionalization.

(4) The slag splashing part of the furnace cannot be controlled accurately. It is not possible to make targeted slagging, especially the slagging part of the slagging line, the control is difficult.

4. Optimization of slag splashing furnace process
4.1. Slag retention control
It is an important technological parameter to determine the amount of slag left in converter reasonably. Ensure enough slag amount, so that the slag spray evenly on the entire surface of the furnace lining, and can form a certain thickness of slag layer.

4.2. Control of final slag composition
The application of slag splashing protection technology has put forward higher requirements for the final slag smelting. It is required that slag not only has the function of desulfurization and dephosphorization, but also can resist the corrosion of molten steel and slag and protect the lining of furnace by spraying slag on the wall of furnace. Therefore, the slagging layer must have a certain degree of fire and viscosity.

(1) Basicity control.
From the perspective of slag splashing protection furnace, it is expected that the basicity is higher, so that the sum of C2S and C3S of the converter end slag can reach 70%~75%. This kind of compound is high melting point material, which is good for improving the fire resistance of slag splashing layer. However, the alkalinility basicity is too high, the smelting process is not easy to be controlled, and the reverse drying can affect the dephosphorization and desulfurization effect, cause waste of raw materials, and cause the rise of furnace bottom. According to the experimental analysis, the basicity of the final slag is controlled from 2.8 to 3.4, the content of sulfur and phosphorus at the end can be controlled below 0.025%, and the residues splashed on the furnace wall have strong corrosion resistance.

(2) Control of MgO content.
MgO and Fe2O3 can be combined to form magnesium ferrite, and the compound can react with MgO to form a solid melt, which is the main high temperature resistant substance in slag.

(3) Control of FeO content.
The final slag has low iron oxide, less C2F(calcium ferrite) in the slag, high melting temperature of RO phase, and low MgO content in the slag when sufficient refractoriness is ensured. In this way, the cost of slag protection furnace is low, and it is easy to obtain high furnace life. In terms of operation, under the same temperature, basicity and MgO conditions, FeO content is low, slag viscosity is large, slag is quick to rise, slag splashing time can be reduced without affecting slag splashing effect.
Reducing erosion can create conditions for slag splashing. The state of the final slag directly affects the effect of slag splashing, with high basicity, high MgO content and low FeO content. Reasonable control of converter slag is the key to slag splashing. From the production practice of slag splashing in converter, it is found that the erosion of slag splashing layer mainly occurs in the later stage of converter smelting and it is the key to control the final slag reasonably. From the production practice of slag splashing in converter, it is found that the erosion of slag splashing layer mainly occurs in the later stage of converter smelting [7].

4.3. Control of slag splashing gun position
Slag splashing gun position has a great influence on the amount of slag splashing, and slag splashing furnace is the most important parameter of field operation. In the process of slag splashing, the position of the gun is too high, the air has great influence, the slag kinetic energy of the upper furnace is insufficient, and it is not easy to hang the gun. The position is too low, the influence of the air is small, which is not conducive to unified slag. After repeated tests at the steel plant site, the position of the gun body is generally controlled at 1200 mm, and the position of the gun body drops to 900 mm when the bottom rises.

4.4. Control of slag splashing time
Slag splashing time is too short, slag has not been fully cooled and mixed, slag conditions are relatively poor. Even if it is splashed on the wall of the furnace, it cannot be normally hung up and cannot be used as a protective furnace. The longer the slag splashing time is, the more slag there is in the furnace lining, leading to the rise of the furnace bottom. If the residue of slag is too small, the furnace bottom will wear out excessively. The average slag splashing time before furnace age is about 1.5 minutes. After a large number of field tests, determine the slag time control at about 25 minutes.

4.5. Control of steel temperature
The steel temperature of converter directly affects the effect of slag splashing. If the furnace temperature is too high, the solubility of MgO will increase, and the content of MgO in the slag will increase. The content of solid MgO in the slag will decrease, and the refractory degree of the slag will decrease. At the same time, too high temperature will also increase the content of FeO in slag, which will inevitably increase the content of RO phase (FeO) and calcium ferrite, reduce the melting point of slag, increase the wettableness of furnace lining, and increase the erosion of magnesium carbon bricks in lining. The service life of furnace lining is increased.

5. Conclusion
The slag splashing furnace protection technology is summarized in this paper commonly used in China at present, and the following conclusions are obtained:

(1) The basic principle, basic method and main process parameters of slag splashing furnace are summarized;
(2) Some problems in slag splashing furnace protection are analyzed
(3) Finally, the optimized design of slag splashing furnace is proposed to provide guidance for practice.

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