Research And Application of Control Technology for The Amount of Slag-roughing In Converter Tapping Process

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Abstract. Series technologies in slag-stopping like “Infrared test for slag-roughing”, “sliding plate in pushing off slag” and the optimization of floating plug have been introduced in this paper. The system operated steadily after install and trial run, have played a good metallurgy effect, and the amount of slag-roughing has been decreased 48.9%, the furnaces ratio of rephosphorization quantity \(\leq 0.003\%\) have been increased 14.38%, yield of alloy Si and Mn have been increased 1.36%, 1.78% respectively, and decreased the consume of deoxidize material and refining slag effectively. The content of \([Ti]\) in bearing steel have been controlled below \(50 \times 10^{-6}\), realized the produce of high quality bearing steel that \([O] \leq 8 \times 10^{-6}\), \([Ti] \leq 30 \times 10^{-6}\), and established the important foundation for the exploitation of high quality steel.

Introduction

With the advance of technique and the products’ structure adjusted constantly, the purity of molten steel turn to be the mainly factor to restrict the development of some high quality steel. Decreasing the amount of slag-roughing in converter is an important link for the improvement of molten steel quality\(^1-2\). Due to the sliding plate can close quickly, sliding plates in slag-stopping can stop slag at prophase and anaphase in the process of taping in converter effectively. Thickness of slag can be controlled at 80~120mm by using floating plug, slag-stopping ball and pneumatic slag stopper, the success rate of slag-stopping is 60%~80%; while it’s can be reached 100% by use sliding plate in slag-stopping and combine with infrared test for slag-roughing in converter tapping process, and the amount of slag-roughing can be controlled below 40mm. Decrease the mount of slag-roughing is beneficial to improve the alloy yield and decrease the quantities of rephosphorize and resulfurize, decrease the consumptions of desoxidant and refining slag, offered a good refining condition and achieved the aim that improve the quality of steel ultimately.

Equipment composition and operating principle

This system is consist of two parts, “pushing off slag” and “infrared test for slag-roughing”, infrared test system collect the information of slag-roughing picture and send operation order to slag-stopping system, and realized automatic control for slag-stopping ultimately.

Slag-stopping system

Slag-stopping system have been designed to use the institution of face pressure bolt and straight pressure type sliding plate, the structure of mechanism was shown as fig.1, it is observed that the system including sliding plates, gap, doorframe and slide-frame, these equipment have been installed on the mounting plate by bolt integral, and the mounting plate have been installed on the junction plate of tapping hole flange by active bolt, and connected tapping hole through inter gap.
The theory of slag-stopping system is that the sliding plates system has been driven by hydraulic cylinder and which installed at the outside of tapping hole, realize the control for the lockage of sliding plate on the basis of actual manufacture requirement. Theory diagram have been shown as fig.2. Operate hydraulic cylinder to close sliding plate while late stage of tapping and keep slag in converter and realize the control of slag-roughing. Not only the late stage of tapping but also close sliding plate before taping, and open it after the converter have been turned to the right angle. And full-automatic slag-stopping could be realized in the process of taping by using infrared test system for slag-roughing.

**Infrared test system for slag-roughing**

Infrared test system for slag-roughing is consists of thermal imager and embrace display terminal, sound-light alarm system too. This system is helpful for hitting the point of slag-roughing and improving the successful rate of slag-stopping. Slag-roughing alarm could be set up based on the requirement of slag-roughing, and the alarm range could be set at 0–20%. For example that it set 15% as alarm point, and if the content of slag in steel reach 15% and raise alarming while taping.

**Optimize for floating plug**

Due to turn down taping, a certain amount of slag have rough while the beginning of taping. In order to improve the service life of sliding plate, floating plug have been used to stop slag in usual, and shown as fig.3. But 30% of converters not play the effect of stopping slag, because of fall off before taping. Therefore, stop slag in early stage of tapping is essential while infrared test and sliding plate in slag-stopping have been used.
It have been observed in practice that service conditions are different for different service time of taping hole, and the size of floating plug have been redesigned to optimize based on it.

**Optimize size**

The size of floating plug have been optimized for the different service time of taping hole, and the size optimization situation have been shown as table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>primary</th>
<th>≤30</th>
<th>&gt;30</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>150</td>
<td>145</td>
<td>160</td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

**Optimize chemical component**

The floating plug appears to be defoliation in advance not only caused by the size of floating plug but also thermal expansibility, which get closely connection with chemical component. The thermal expansion coefficient of primary floating plug is low, and it’s drop out easily while the tapping hole have been scoured to be larger. And added a certain ratio of vermiculite that the expansion coefficient is larger, and the contact situation have been optimized obviously, and ratio of successful push off slag have been increased effectively.

**Usage of the equipment**

Comparing the amount of slag that rough from taping hole while taping for primary and optimized process, the new process has gotten better metallurgy effect after the system have been commissioning and operated stable.

**Decreasing the amount of slag-stopping**

On the promise of not add active lime and other slag charges while the system operate steadily, the thickness of slag in furnace have been measured after tapping finished at platform, and thickness date of 103 furnaces for new process and 116 furnaces for primary process have been obtained. The measured results have been counted and shows as fig.4, as fig shows that the thickness of slag have been controlled at 22~40mm and 34.2mm in average but 33~84mm and 64.9mm in average for primary process, the thickness of slag have been decreased 47.3% by comparing the two processes.
In order to quantificat the effects of the process, research group have carried out two rounds test for measuring the amount of roughing slag by using barium carbonate[3], a certain amount of BaCO$_3$ have been added into furnaces at the ending of tapping (will be molten and resolved while $T \geq 1297^\circ C$), and slag samples have been taken at LF while outbound. The content of BaO have been detected and analyzed. The specific counting process was show as type(1) and (2)[4].

$$\text{BaCO}_3 \rightarrow \text{BaO} + \text{CO}_2$$

$$\frac{(a \cdot 153)}{A + B} = C$$

Annotation: $a$—the amount of BaCO$_3$ added at the end of tapping /kg·t$_{steel}^{-1}$;

$A$—the amount of roughing slag /kg·t$_{steel}^{-1}$;

$B$—the amount of slag added in /kg·t$_{steel}^{-1}$;

$C$—ratio of BaO in slag while LF outbound /%.

The test results have been shown as table2, and the amount of slag-roughing have been decreased obviously for the optimized process, and decreased 4.99kg·t$_{steel}^{-1}$, it’s 48.9% compared with the primary process.

<table>
<thead>
<tr>
<th>Process</th>
<th>Added into BaCO$<em>3$ (kg·t$</em>{steel}^{-1}$)</th>
<th>BaCO$<em>3$ added into(kg·t$</em>{steel}^{-1}$)</th>
<th>Content of BaO while outbound LF( %)</th>
<th>Amount of roughing slag(kg·t$_{steel}^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1.23</td>
<td>0.38</td>
<td>2.59</td>
<td>10.21</td>
</tr>
<tr>
<td>Optimized</td>
<td>1.12</td>
<td>0.38</td>
<td>4.67</td>
<td>5.22</td>
</tr>
</tbody>
</table>

Shows as the results of thickness measurement and calibration test of roughing slag that the control level of roughing slag have been improved effectively, the calibration result has been shown as fig.5.
Decreasing rephosphorization quantity

Rephosphorization quantity that after tapping was mainly effected by the amount of converter slag-stopping and the deoxidize condition for slag, comparing rephosphorization between primary and optimized processes and the results have been shown as fig.6. That the optimized process was 0.0018%, but primary process was 0.0025%, it has been decreased 0.0007%, and the ratio of furnaces that below 0.003% have been improved from 60.34% to 74.72% and improved 14.38%.

![Fig.6 The condition of rephosphorization control](image)

Decreasing the consumption of slag charge

Resulfurization after converter was mainly come from the slag and which is oxidability, in order to ensure the control for resulfurization, lime have been added into refining slag to keep a certain basicity. In the condition of a certain content of sulfur in molten steel, different amount of lime have been added into furnace. Take statistics to the amount of lime that added into furnace for one type of steel in different process, and results shows as fig.7. Shows that the major furnaces have above 3.05kg/t\textsubscript{steel} for primary process, but <3.05kg/t\textsubscript{steel} for optimized process. And the amount of lime that added into furnace in average have been shown as fig.8, the optimized process controlled at 2.64kg/t\textsubscript{steel}, but 3.08kg/t\textsubscript{steel} for primary, that have been decreased 0.44kg/t\textsubscript{steel}.

![Fig.7 The amount of lime have been added into furnaces](image)

![Fig.8 Amount of lime added into furnace in average](image)
Decrease the consumption of deoxidant

The consumption of aluminium wire for 26 furnaces same grade steel have been counted and shown as table 3, as table 3 shows that the consumption of aluminium wire was 3.31 m/t_steel for primary process that the ending point C% was 0.04%~0.08% and 0.07% in average, but 3.00 m/t_steel for the optimized process that the ending point C% was 0.03%~0.07% and 0.05% in average. That means the consumption of aluminium wire have been decreased obviously after optimized process has been used.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Ending point [C] (%)</th>
<th>Aluminium wire (m·t_steel⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Range 0.04-0.08</td>
<td>2.67-3.44</td>
</tr>
<tr>
<td></td>
<td>Average 0.07</td>
<td>3.31</td>
</tr>
<tr>
<td>Optimized</td>
<td>Range 0.03-0.07</td>
<td>2.44-3.44</td>
</tr>
<tr>
<td></td>
<td>Average 0.05</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Improve and stabilize the yield of alloy

The yield of Si and Mn in the complete flow scheme have been counted for rail steel, yield of Si for primary process is 95.96% and Mn is 96.87% in average, and have been improved 1.36%, 1.78% respectively, Si reached 97.32% and Mn 98.6% after optimized. For the costs of alloy in converter and refining, Si and Mn have saved 1.26/t_steel.

Meet the special requirement of high quality steel

Smelt bearing steel with hot metal which contain titanium, and the ending slag in converter contain a certain amount of TiO₂. TiO₂ has been restored into molten steel while refining and the oxidability of slag decreasing. Compare the control situations between primary and optimized process, the results have been shown as fig.9. The content of Ti have been controlled from \( \geq 50 \times 10^{-6} \) to \(< 50 \times 10^{-6}\) for all furnaces, and 8 furnaces bearing steel realize \([\text{Ti}] \leq 8 \times 10^{-6}\) and \([\text{Ti}] \leq 30 \times 10^{-6}\).

Conclusions

1. This technology realized automatic control for slag-stopping in the process of tapping in converter, the system operated stably and economical.

2. It’s effectively and the metallurgical effects are remarkable: the amount of slag-stopping have been controlled at 5.22kg/t_steel and the thickness was 34.2mm in average, have been decreased 47.3%; the furnaces ratio that rephosphorization below 0.003% have been increased 14.38%; yield of alloy Si, Mn increased 1.36% and 1.78% respectively; the consumption of deoxidize material and refining slag have been decreased obviously.

3. It’s realize the production of high quality steel: [Ti] in bearing steel has been controlled below \(50 \times 10^{-6}\) and the production of high quality bearing steel that \( T[\text{O}] \leq 8 \times 10^{-6}\)、\([\text{Ti}] \leq 30 \times 10^{-6}\) can be achieved.
Reference


