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

Li Hongguang[1, a *], Chen Tianming [1,b] Chen Liang[1,c] and Guo Dianrong [2,d]

[1] Pangang group research institute co., LTD, Si Chuan, PanZhihua 617000

[2] Pangang group steel vanadium and titanium co., LTD, Si Chuan, PanZhihua 617062

[a]903281775@qq.com

Keywords: Slag-stopping; Slag-roughing; Rephosphorization; Yield of alloy; Bearing steel.

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 ≤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 50×10^{-6}, realized the produce of high quality bearing steel that $T[O]\leq8\times10^{-6}$、 $[Ti]\leq30\times10^{-6}$, and established the important foundation for the exploitation of high quality steel.

Introduction

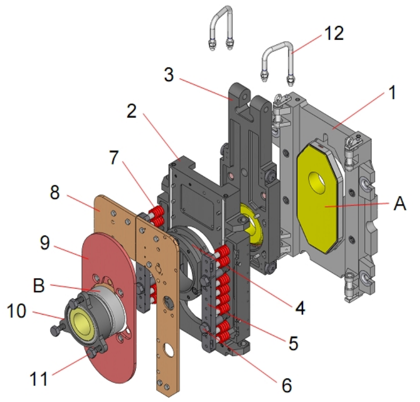
With the advance of technique and the products' structure adjusted constantly, the purity of molten steel turn to be the mainly factor to restrict the development of some high quality steel. Decreasing the amount of slag-roughing in converter is an important link for the improvement of molten steel quality[1~2]. 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 taping hole through inter gap.



1. Mounting plate
2. Door frame
3. Sliding frame
4. Top tight knot
5. Spring bearer plate
6. Bolt surface pressure
7. Spring
8. Fixed thermal baffle
9. Active thermal baffle
10. Top binder
11. Bolt
12. Air cooling pipe
A. Sliding brick

Fig.1 Structure chart of sliding plate system

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 taping 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.

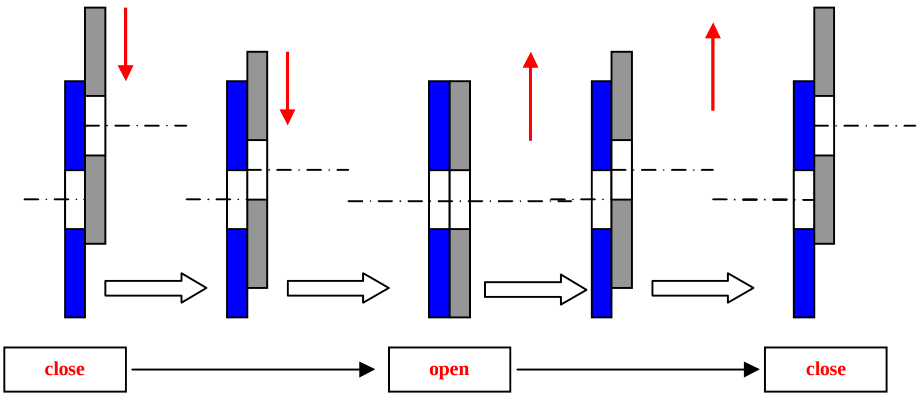


Fig.2 Theory program of slag-stopping

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.

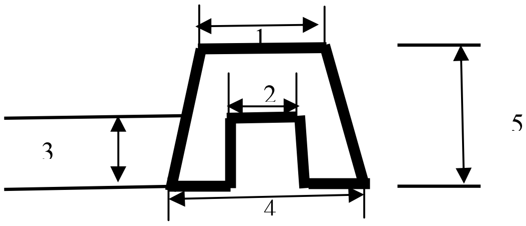


Fig.3 Schematic diagram of floating plug

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 table1.

Table 1 Size of floating plug optimizing [mm]

No.	primary	optimized	
		≤30	>30
1	100	80	80
2	40	40	40
3	100	100	100
4	150	145	160
5	200	200	200

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.

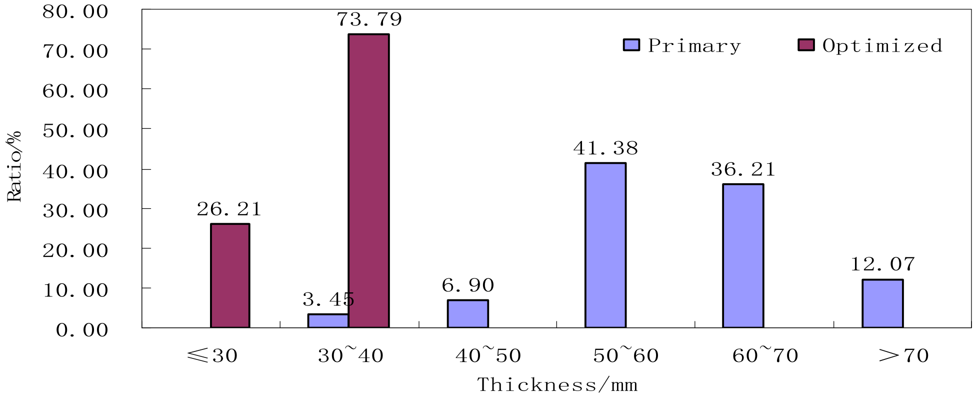


Fig.4 Thickness of slag

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≥1297℃), 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].

$$BaCO_3 \rightarrow BaO + CO_2 \quad (1)$$

$$\frac{(a \bullet \frac{153}{197})}{A+B} = C \quad (2)$$

Annotation: a—the amount of $BaCO_3$ added at the end of tapping /$kg \cdot t_{steel}^{-1}$;

A—the amount of roughing slag /$kg \cdot t_{steel}^{-1}$;

B—the amount of slag added in /$kg \cdot t_{steel}^{-1}$;

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 4.99$kg \cdot t_{steel}^{-1}$, it's 48.9% compared with the primary process.

Tabel 2 Testing results of lag-roughing

Process	Added into ($kg \cdot t_{steel}^{-1}$)	$BaCO_3$ added into($kg \cdot t_{钢}^{-1}$)	Content of BaO while outbound LF(%)	Amount of roughing slag($kg \cdot tsteel^{-1}$)
Primary	1.23	0.38	2.59	10.21
Optimized	1.12	0.38	4.67	5.22

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.

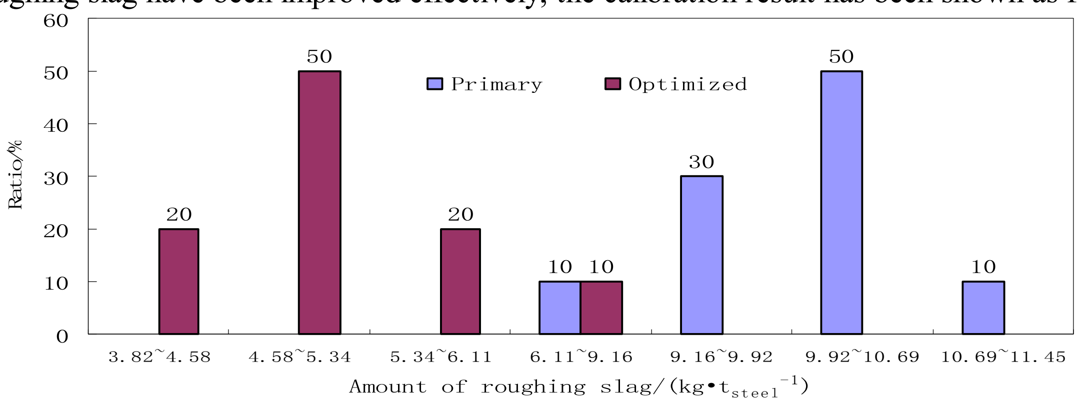


Fig.5 The distribution of slag-roughing

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%.

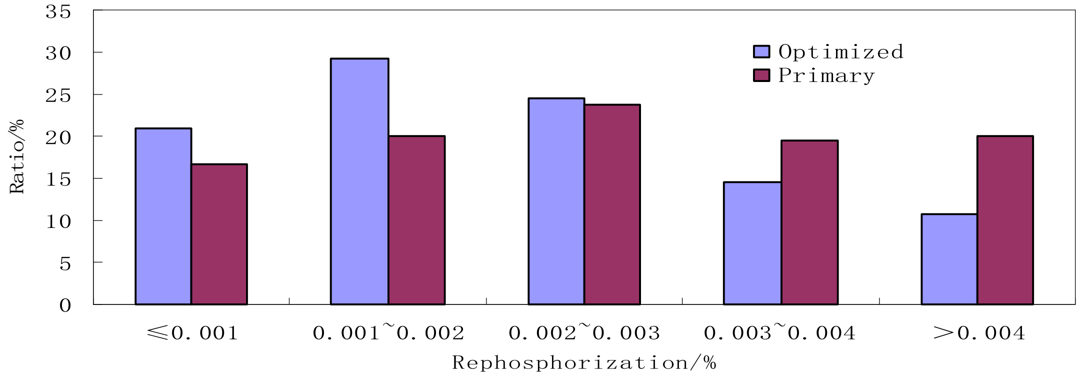


Fig.6 The condition of rephosphorization control

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_{steel} for primary process, but <3.05kg/t_{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_{steel}, but 3.08kg/t_{steel} for primary, that have been decreased 0.44kg/t_{steel}.

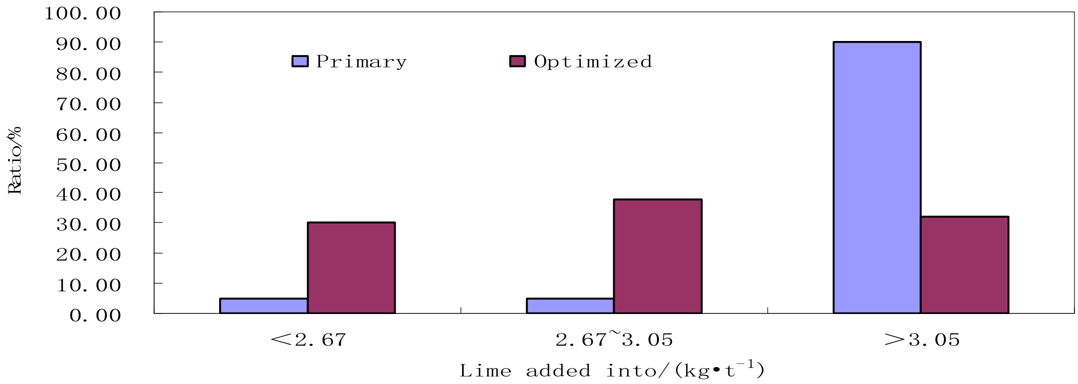


Fig.7 The amount of lime have been added into furnaces

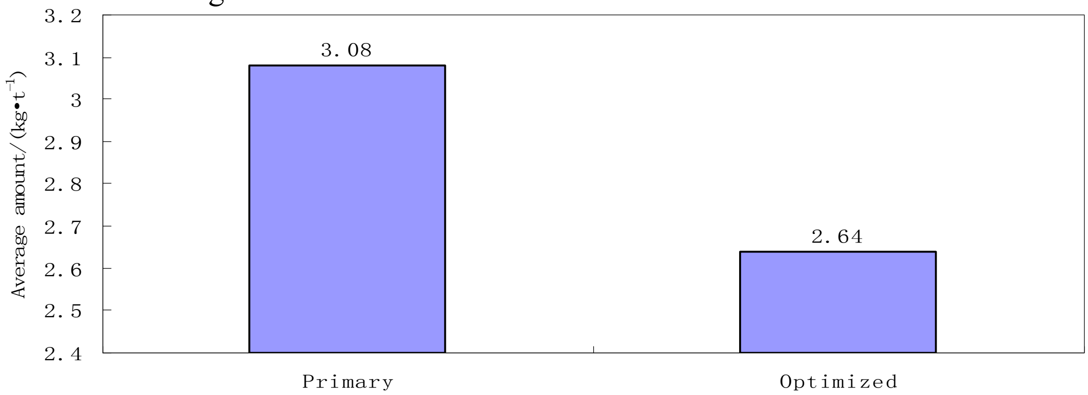


Fig.8 Amount of lime added into furnace in average

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 3.31m/$t_{steel,}$ 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 3 Condition of deoxidant consume

Projects		Ending point [C] (%)	Aluminium wire ($m\cdot t_{steel}^{-1}$)
Primary	Range	0.04-0.08	2.67-3.44
	Average	0.07	3.31
Optimized	Range	0.03-0.07	2.44-3.44
	Average	0.05	3.00

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 TiO_2. TiO_2 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 $\geq 50\times10^{-6}$ to $<50\times10^{-6}$ for all furnaces, and 8 furnaces bearing steel realize $T[O]\leq 8\times10^{-6}$ and $[Ti]\leq 30\times10^{-6}$.

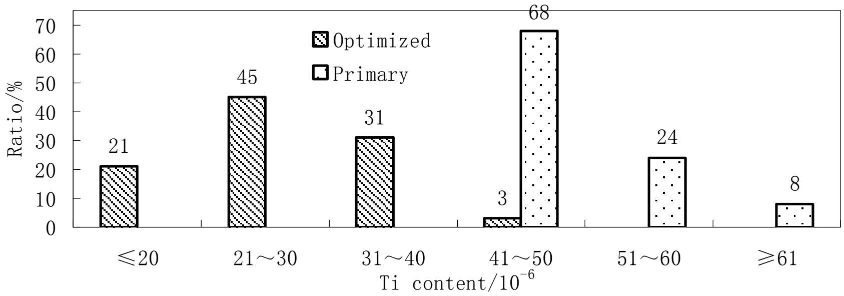


Fig.9 The control of [Ti] in bearing steel

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 50×10^{-6} and the production of high quality bearing steel that $T[O]\leq 8\times10^{-6}$、$[Ti]\leq 30\times10^{-6}$ can be achieved.

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