Research on control measures of N, T[O] and Ti in Bearing Steel

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Abstract: In allusion to the requirements of bearing steel for ultralow T[O], Ti, analyzing the effects of slag system to T[O] by FACTSAGE thermodynamic calculation. The calculation results shows that the slag system of bearing steel should be controlled in the area that SiO_2 0%~20%、Al_2O_3 25%~45%、CaO 45%~65%,it is helpful to control T[O]; the conclusion could be got by analyzing the control of T[O] and the content of Ti that control Als at 0.02%～0.08% is reasonable and basicity of slag need to be controlled at 5~8 in the smelting process of LF. Commerical test shows that in the bearing steel which was trial-produced TO] $\leq 15\times10^{-6}$,N$\leq 60\times10^{-6}$,[Ti]$\leq 30\times10^{-6}$, and achieve batch production for ultralow oxygen bearing steel at last.

Introduction

With the developing of science and technology, the service condition of bearing steel is more and more scurviness, and the requirements for bearing steel is more and more slashing. That means bearing steel need have favorable degree of purity, reliability and fatigue life. Bearing steel is one kind of the steel which is the most demanding, most difficult to produce and the most items to inspect in numerous of steel[1~3]. In order to meet the requirements of high-end bearing steel for Ti, T[O] and N, by the means of thermodynamic calculate for smelting slag system and analysis the control of Ti content, optimum proposal for technology have been proposed. Test result shows that [Ti]$\leq 30\times10^{-6}$,T[O]$\leq 15\times10^{-6}$,[N]$\leq 60\times10^{-6}$, after optimize technology, the chamber machine have been provided with the ability of volume production for bearing steel.

Analysis and control the compose of slag system

Most of special steel enterprises inland which produce bearing steel by the process of UHP(or BOF)一LF一VD一CC. The process of bearing steel GCr15 production for Beiman special steel is 90t EBT一LF(vn)一240mmx240mm CC, and refining by using high basicity refining slag that basicity degree is 4.46, and make vacuum treatment 25min for liquid steel, and keep [Al]s≤0.03%. Researches on refining slag for bearing steel is more, researches shows that high basicity refining slag is helpful to control T[O] for bearing steel[3~6]. But researches on the effects of slag system on T[O] control was lack of specific value, and it is necessary to calculate the composition of slag theoretically.

As figure1 shows, the results calculated by the phase diagram module of FACTSAGE software shows that two low-melting-point areas have been included in ternary non-metallic inclusion system $CaO-SiO_2-Al_2O_3$, the smelting point of area 1′ is inferior to 1400℃, the range of constituent is SiO_2 28%~70%、Al_2O_3 3%~40%、CaO 10%~55%; the smelting point of area 2′ is inferior to 1400℃ and the range of constituent is SiO_2 0%~10%、Al_2O_3 35%~50%、CaO 47%~57%.

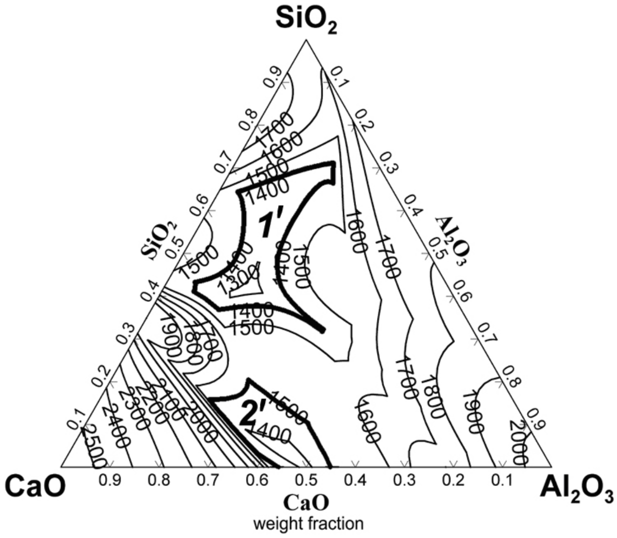

Fig1. CaO-SiO_2-Al_2O_3 ternary system phase-diagram calculated by FACTSAGE software

Contour line of activity for a[O], a[Al] and a[Ca] have been shown as figure2, figure3 and figure4 respectively. Flowing results could be got from figures:

(1) in order to realize the production of ultralow [O] and ultralow inclusions bearing steel, aluminium deosidation need to be taken, and slag system should be controlled to be calcium aluminate system which is low-melting-point, T[O] could be controlled about 1ppm theoretically.

(2) Als in steel need to be controlled ≥0.01%, considering the reactivity of liquid steel could not be balance in actual production, Als in liquid steel should be controlled above 0.002% for ultralow [O] bearing steel.

(3) The basis of low-melting-point calcium aluminate system(≤1500℃) was: SiO_2 0%~20%、Al_2O_3 25%~45%、CaO 45%~65%.

(4) Refining by using high basicity refining slag, the content of Ca in liquid steel controlled below 5ppm, and requirements could be met.

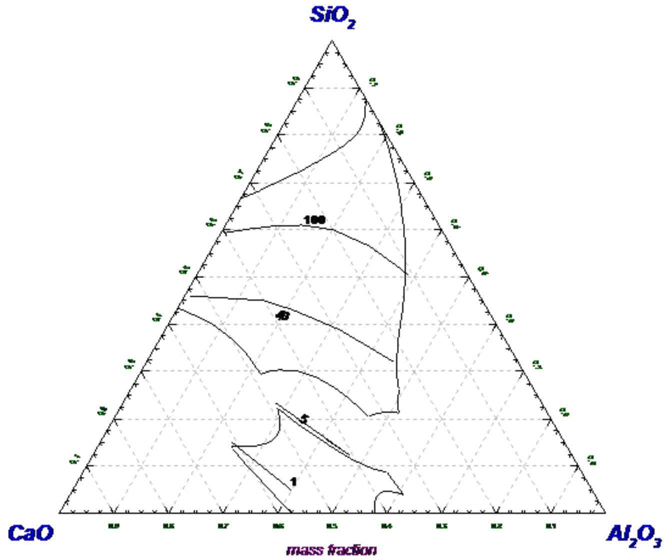

Fig2. Contour line of a[O]

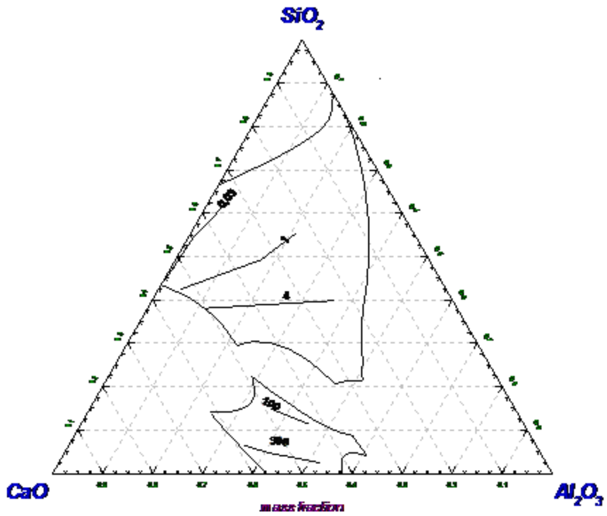

Fig3. Contour line of a[Al]

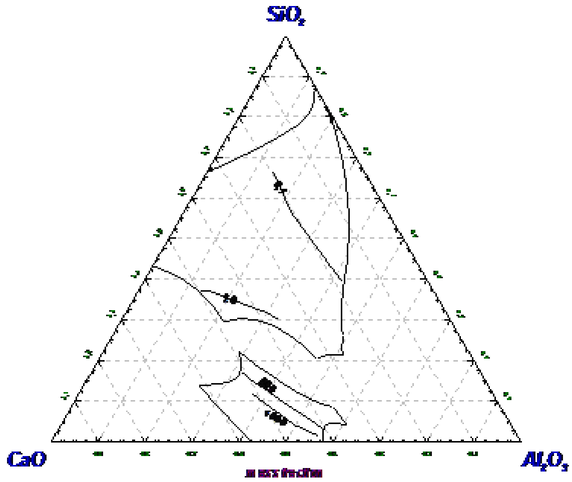

Fig4. Contour line of a[Ca]

Analysis for the content of Ti

With the content of [O] decreasing the fatigue life have been influenced more extruded for bearing steel. And fatigue life of bearing steel decreasing rapid with the increasing of Ti content while w(Ti)＞0.005 %[7].Case of control for low-end bearing steel which had been produced have been analyzed, and the results have been shown as figure5, conclusion that lower [C] at the end of converter and the content of [Ti] at the end of converter was lower too.

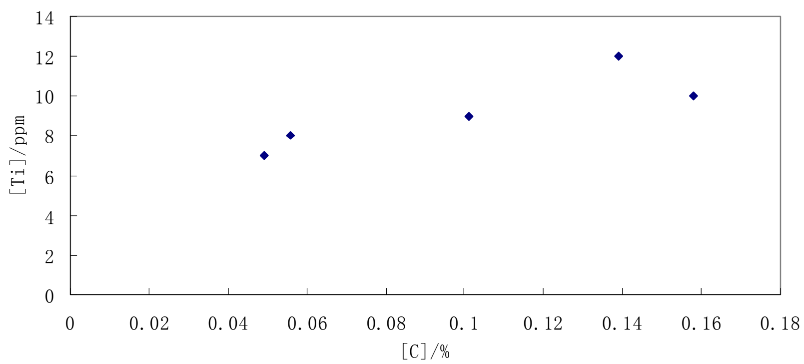

Fig5. Relationship between [C] and [Ti] at the end of converter

Shows as figure6, the content of [Ti] was about 10×10^{-6} while the content of [C] at the end of converter have been controlled at 0.07%～0.10%, increasing Ti was mainly in the process of LF refining, but RH and continuous casting not almost. So control for the amount of slag which come from converter need to be reinforced, slag should to be removed before LF for ultralow titanium bearing steel on the other hand.

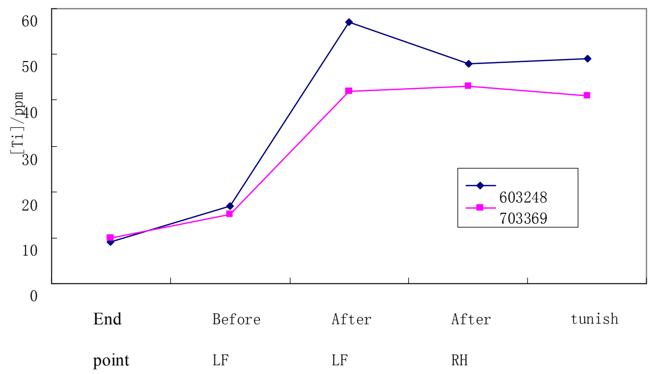

Fig6. change of [Ti] in the process of smelting for representative furnaces

The content of [Ti] was 0.005%~0.007% after LF refining, the amount of titanium increased in the process of LF refining was 0~53ppm, 24ppm in average, reaction between [Al] and (TiO_2) under the condition of reducibility, and caused [Ti] increased. As figure7 shows that the relationship between Als and [Ti] was unconspicuous while liquid steel have been draw up at LF station.

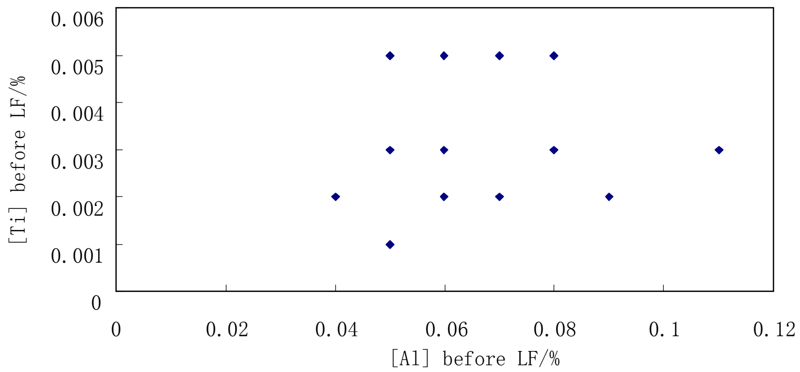

Fig7. Relationship between Als and [Ti] at the beginning of LF

Shows as figure8, Als at the beginning of LF have a certain relationship with the increment of [Ti] in the process of LF. The amount of (TiO_2) which have been restore was few while Als≤0.08%, but increased obviously while Als≥0.08%。

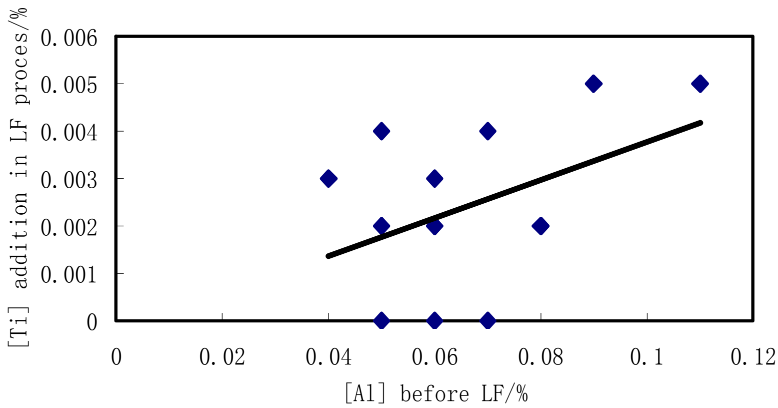

Fig8. Relationship between Als at the beginning of LF and increment of [Ti] in the process of LF

Shows as figure9, the amount of (TiO_2) which was restored increased obviously while at the end of LF Als≥0.07%.

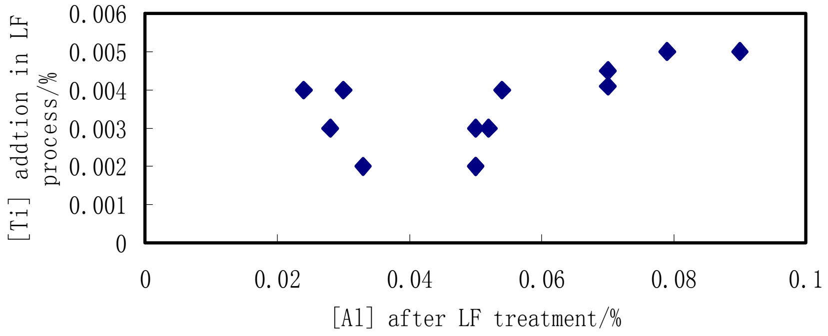

Fig9. Relationship between Als at the end of LF and increment of [Ti] in the process of LF

Influence of the compose of ladle slag on the increment of titanium in the process of LF refining were shown as figure10 and figure11. As figures show that percentage composition of TiO_2 in ladle slag was more the amount of increment for titanium in the process of LF refining was more too; basicity of ladle slag after LF refining was more the increment of titanium was more, but basicity is less affected relatively.

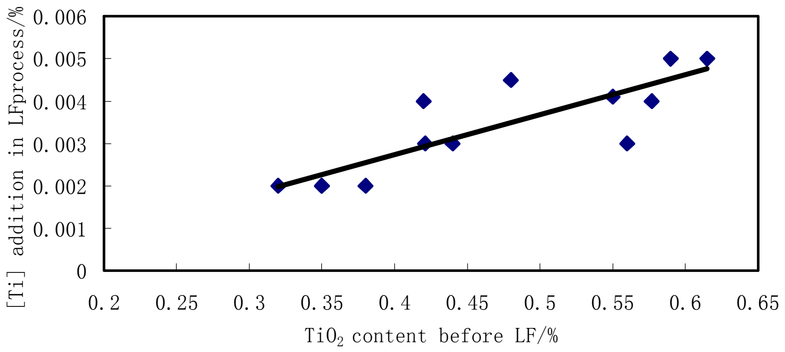

Fig10. Relationship between content of TiO2 in ladle slag and increment of Ti

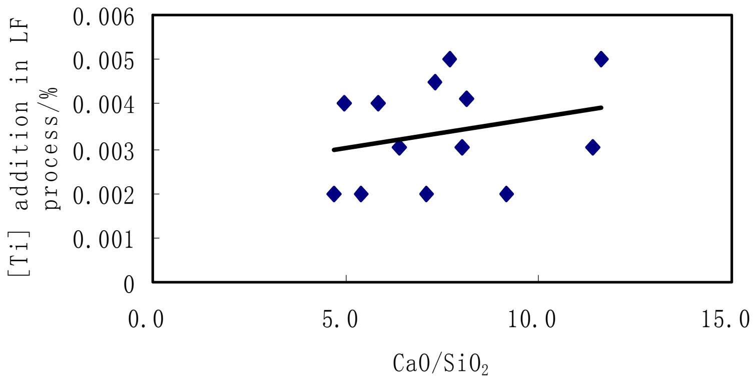

Fig11. Relationship between the basicityof ladle slag and increment of Ti

mainly measures have been taken

Based on the above research, flowing measures have been taken:

(1) by using the technology of semi-deoxidize, and control the content of Als at 0.06%~0.08% before LF refining by feeding aluminium wire at the station of argon blowing where after converter.

(2) Sluggishing slag before tapping, and decreasing the amount of slag by using skateboard to push off slag.

(3) Non-aluminum deoxidation in the process of refining, increase the content of Al_2O_3 for refining ladle slag, the goal composition of refining slag is: SiO_2 0%~10%、Al_2O_3 30%~35%、

CaO50%~55%、MgO≤10%, and TFe in slag is lower and better.

(4) Control cycle time in RH ≥20min, and ensure the time of soft argon blow more than 10min.

(5) Keep argon blowing in the process of converter smelting, protect casting, increasing the amount of covering agent for the first furnace.

Test results and analysis

Detect the slag sample of process

Results of the composition of slag at the end of converter have been shown as table1. as table 1 shows that TFe of slag have been control below 20% for most of furnaces, basicity have been control at about 3.5 stable, and reach the design requirement of project.

Table1 slag composition at the end of converter

No.	composition/%					CaO/SiO_2
	CaO	SiO_2	Al_2O_3	TFe	TiO_2	
603248	46.67	13.71	1.54	16.15	0.366	3.4
603250	43.96	12.83	1.77	18.4	0.267	3.4
603254	47.72	13.18	1.59	15.1	0.263	3.6
703369	41.67	11.83	1.63	21.4	0.289	3.5

The composition of refining slag that at the end of LF have been shown as table2, the composition between two rounds tests are basically the same. Basicity CaO/SiO_2 have been control at 5~11.6 and 7.2 in average, value of CaO/Al_2O_3 have been controlled at 2.3~3.9. reach the requirement of industrial manufacture.

Table2 Composition of LF refining slag that at the end of LF %

Tundish No.	No.	CaO	MgO	MnO	TFe	SiO_2	TiO_2	Al_2O_3	CaO/SiO_2	CaO/Al_2O_3
8furnaces Continuous casting	603248	59.51	2.65	0.178	2.1	7.31	0.206	20.97	8.1	2.8
	603250	60.76	2.77	0.214	0.598	11.23	0.11	18.3	5.4	3.3
	603251	60.3	2.96	0.132	0.662	8.27	0.156	19.52	7.3	3.1
	603253	63.18	2.39	0.103	0.409	8.24	0.132	20.3	7.7	3.1
	603254	62.98	0.911	0.26	0.826	5.53	0.156	23.72	11.4	2.7
	603255	59.96	5.31	0.404	0.829	12.73	0.222	15.65	4.7	3.8
	703368	60.68	6.29	0.175	0.408	12.18	0.187	15.58	5.0	3.9
	703369	59.53	5.26	0.117	0.282	6.49	0.168	23.76	9.2	2.5

Ladle slag that at the end of RH have been shown as table3, compare with LF refining slag, it could be found that the composition change seldom.

Table3 Composition of slag that at the end of RH

No.	composition/%							CaO/SiO_2	CaO/Al_2O_3
	CaO	SiO_2	Al_2O_3	FeO	MgO	MnO	TiO_2		
703100	58.16	9.17	20.82	0.772	5.09	0.122	0.516	6.3	2.8
602899	53.34	9.38	24.23	0.836	6.76	0.125	0.560	5.7	2.2
602903	57.9	9.6	20.02	1.42	5.7	0.14	0.613	6.0	2.9
602902	60.43	8.44	17.06	0.772	4.78	0.106	0.298	7.2	3.5
602901	57.34	7.56	23.1	0.772	5.65	0.127	0.293	7.6	2.5
703098	57.45	4.37	22.98	0.772	6.33	0.102	0.235	13.1	2.5

T[O], N

Test results of T[O] and N for crystallizer steel samples have been shown as table4, the content of N have been controlled below 60ppm, T[O] was below 10ppm.

Table4 Test results of T[O] and N for crystallizer steel samples ppm

tundish	No.	N	T [O]
8furnaces continuous casting	603248	60	8
	603250	59	9
	603251	58	7
	603253	47	6
	603254	55	8
	603255	58	9
	703368	55	9
	703369	48	6

Content of [N] in the process of smelting for representative furnaces have been shown as figure 12. as figure shows that the process form the end of LF refining to continuous casting content of N increased a little bit, that means the effects of protect casting was well.

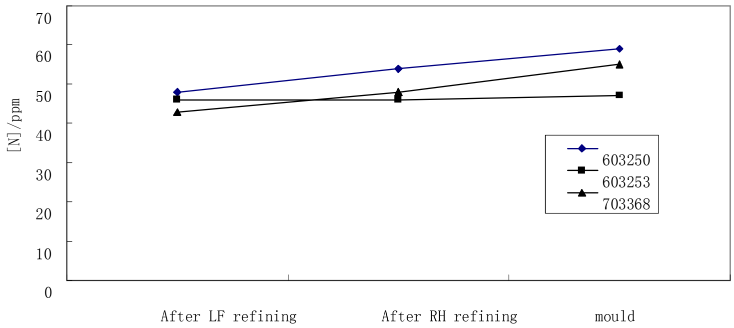

Fig12. Change of [N] in the process of smelting for representative furnaces

Content of Ti

Content of Ti in testing bearing steel billets have been shown as table 5. [Ti] have been controlled at 20×10^{-6}～30×10^{-6} , 25.6×10^{-6} in average.

Table5 [Ti] of end product

	$[Ti]/10^{-6}$	Quantity/furnace
minimum	20	8
maximum	30	
average	25.6	

Conclusions

(1) Research the key technology to control T[O]、Ti、N for the difficulty that limit bearing steel produce in the process of BOF in Panzhihua steel and vanadium, and have exploited smelting technology in the process of converter-square billet continuous casting produce bearing steel by using titaniferous liquid iron.

(2) Have carried out theoretical analyze for the technology to control T[O] and inclusions in bearing steel by using FACTSAGE sofrware. T[O] of trial-produce bearing steel have been controlled below 10×10^{-6}.

(3) By carrying out theoretical analyze for the control of Ti, technical measures have been taken to control the amount of slag at the end of converter and LF refining parameter, have formed the platform to produce bearing steel that have the requirements for $[Ti]\leq30\times10^{-6}$ at last.

(4) By taken measures like: argon blowing in whole journey, protective casting, increase covering agent for the first furnace of one tundish, and the content of N in bearing steel have been control at 47×10^{-6}～60×10^{-6} and 48.2×10^{-6} in average at last.

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