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PROCESS DESIGN AND LIFE ANYLYSIS OF TUNDISH LINING

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The working lining of continuous casting tundish is made of magnesia dry material with short service life. It is found that the refractory lining cast steel zone is the key to influence the service life of tundish. Therefore, the material formula of tundish casting steel area is developed, and the construction is carried out in different parts, so that the balanced corrosion can improve the working life of tundish lining, reduce the turnover of tundish, improve the yield of steel, and reduce the consumption of steel resistant material per ton, which has good economic and social benefits.

Keywords: steel, tundish, corrosion, dry material formula, service life

INTRODUCTION

Tundish is a device used for excess molten steel between ladle and crystallizer. For multiflow continuous casting machine, the liquid steel is divided by the tundish. The liquid steel stored in tundish plays a connecting role in ladle changing when multiple furnaces are poured continuously. In the casting process, the tundish height fluctuation range is small, so it can be used to stabilize the casting process of molten steel and reduce the erosion of steel flow on the solidified shell of crystallizer. Tundish can remove the nonmetallic inclusions in the steel when it is in liquid state. Tundish can improve the flow condition of molten steel and can remove the nonmetallic inclusion in the steel [1].

Tundish refractory lining mainly includes insulation lining, permanent lining and working lining as shown in Figure 1. The insulation liner (10 ~ 30 mm) is next to the tundish steel shell, which is mainly used to keep the molten steel warm and reduce the temperature drop of the molten steel in the pouring process. The permanent lining (100 ~ 200 mm) is in contact with the insulation layer, mainly playing the role of safety insulation. The working liner (20 ~ 50 mm) is in contact with molten steel, which is the key part. The layer material in the use process and construction process should strive to improve labor productivity, with a good baking adaptability, the requirements of drying lining material hardening fast, non-burst, good strength, can increase the utilization rate of the tunic, extend the use cycle of the central question package, reduce the number of spare package. The working lining material should be able to have good adhesion with the permanent layer, have good high temperature performance and good chemical stability, will not cause pollution to the liquid steel. In the process of use, it should have good resistance to slag erosion and penetration, as well as resistance to molten steel and slag scouring, which is beneficial to improve the service life of the working lining of the central question package. The work lining is divided into cast-steel area, water mouth area and bottom area through practice summary and analysis, and different refractory materials and process design are used respectively [2-3].

The tundish volume of continuous casting single flow slab is 30 tons. The original tundish working lining is made of the same formula of magnesia dry material, with an average service life of 13,5 hours. After practice and data analysis, the key goal of improving the working life of tundish lining in stages was put forward. The working life of tundish lining in the first stage reached more than 16 hours.

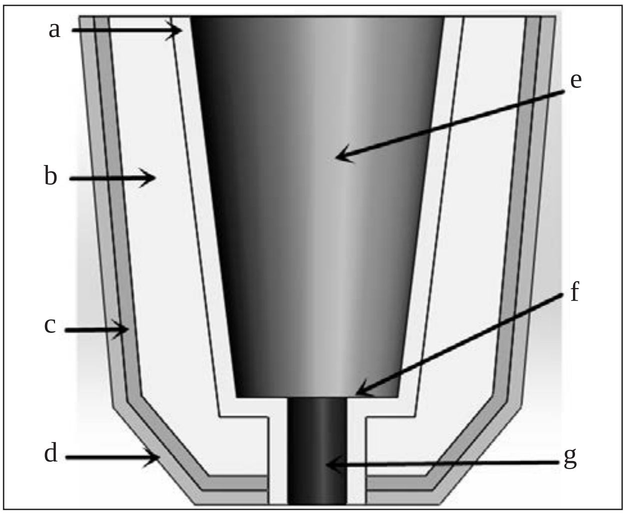

Figure 1 Tundish composition
a) working lining, b) permanent lining
c) insulation lining, d) steel plate
e) cast steel area, f) water mouth area
g) bottom area

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According to the tundish working conditions, each part of the tundish working lining erosion causes are analyzed, according to different site conditions of use particularity, respectively developed casting steel area, water mouth area and the bottom of the bag using magnesia and magnesium chrome dry material, division, technology in construction, achieve balanced erosion and reduce the dry material cost of raw materials. Through practical application, the average service life of tundish lining was increased to 16,6 hours and the average number of continuous casting cans was 30. The maximum service life is 18,26 hours, and the maximum number of continuous pouring cans is 32 cans.

ANALYSIS ON THE CAUSE OF TUNDISH LINING DAMAGE

The working lining of continuous casting tundish mainly consists of three parts: casting steel cladding wall, water mouth cladding wall and bottom lining. The wall lining thickness in casting steel area is 60 - 70 mm, and the wall lining thickness in water mouth area is 60 - 70 mm, among which the bottom lining thickness is 90 mm. In continuous casting, the molten steel flows into the tundish turbulence unit through the ladle's long nozzle. After changing the flow direction through the turbulence unit, the molten steel flows into the nozzle area through the slag retaining wall and dam. The flow field of molten steel changes after passing through tundra turbulence, slag retaining wall and slag dam, and the working lining of tundra is scoured by molten steel and corroded by slag. The cause of corrosion is analyzed as follows:

Tundish cast steel zone: the molten steel rushes to the slag retaining wall and cladding wall according to the flow field direction through the turbulence apparatus, and is subjected to the mechanical scouring of high-temperature molten steel. With the increase of casting time, the amount of slag increases, especially in the later stage of pouring each pack of molten steel, some of the steel slag flows into the tundish with the molten steel, which seriously corrode the slag line.

Tundish water mouth area: when molten steel flows through the slag retaining wall and dam, its impact force is significantly reduced compared with the initial flow into the pouring steel area, and the mechanical scouring strength of molten steel in the nozzle area is also significantly reduced. In addition, when the molten steel flows through the slag retaining wall to the inlet area, most of the steel slag is prevented to stay in the cast steel area, thus greatly reducing the slag erosion of tundish slag on the working slag line of the nozzle area.

Bottom of tundish: the molten steel first enters the bottom of the turbulizer and then enters the bottom of the tundish. In the initial stage, the bottom of the ladle should withstand the scouring of the molten steel from the turbulizer. As the liquid level of the molten steel rises, the agitation of the molten steel gradually decreases and tends to be stable.

STUDY ON IMPROVING THE SERVICE LIFE OF TUNDISH LINING

Based on the analysis of the reasons for the lining damage, it is concluded that the service life of the lining should be improved from two aspects: the first is to optimize the formula so that the lining parts can achieve balanced corrosion; the second is to optimize the operation process to improve the reliability.

The original tundish lining is made of a single magnesium dry material formula, and its service life is 13.5 hours. It was found that the damage of tundish lining was caused by the heavy erosion of sintering and slag line in casting steel area. By improving the sinter resistance and erosion resistance of the slag line, the service life of the tunic lining can be further improved. The residual lining at the bottom of the middle bag is thick. By optimizing the formula and under the premise of the same binder, three formulations are optimized, which are respectively used in the nozzle area, the casting steel area and the bottom of the bag.

Table 1 **Chemical composition of raw materials /%**

Composition	Fused sand	Mg-Cr sand	Mg powder	Mg clinker
MgO	96,12	65,45	95,42	92,44
SiO_2	1,06	0,76	1,53	4,09
Cr_2O_3	–	19,88	–	–
Fe_2O_3	0,67	7,84	0,77	1,03
Al_2O_3	0,19	4,35	0,26	0,53
CaO	1,68	0,96	1,95	1,61
Alkali	0,28	0,76	0,07	0,3

Table 2 **Test formula /%**

Area	Mg clinker	Fused sand	Mg-Cr sand	Composite binder
3#Water mouth	80	8	2	10
2#Cast steel	–	60	30	10
1#Bottom	85	–	5	10

Table 3 **Test index of tundish dry material**

Formula		3#	2#	1#
Flexural strength /MPa	250 °C× 1 h	1,15	1,17	1,13
	1 550 °C × 3 h	1,50	1,48	3,30
Volume density /(g/cm³)	250 °C × 1 h	1,80	1,82	1,78
	1 550 °C × 3 h	1,86	1,86	1,89
Line gradient after burn /%		-1,46	-1,25	-1,78
MgO /%		86,53	–	84,64
$MgO+Cr_2O_3$ /%		–	88,21	
SiO_2 /%		5,15	3,06	7,42
CaO /%		1,92	1,90	1,80

Table 4 **Chemical analysis of test slag /%**

Al_2O_3	Fe_2O_3	Na_2O	MgO	K_2O	TiO_2
32,87	1,57	0,33	8,81	0,11	0,57
F	SO_3	MnO	CaO	SiO_2	
0,28	0,87	0,79	41,96	11,84	

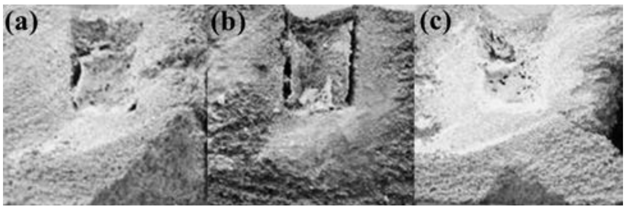

Figure 2 Static slag samples
(a) water mouth area (b) cast steel area (c) bottom area

According to the idea of optimized formulation design, different magnesia raw materials are selected according to the service conditions of different parts, so as to achieve the best cost performance under the premise of guaranteeing the service life. The physical and chemical indexes of the main raw materials are shown in Table 1, and the test formula is shown in Table 2.

According to the ratio, weigh sample, mix and make sample. Heat the drying box to 250 °C, put the mold sample in the drying box for 1 hour, take it out and cool it. After the sample is dried, the mould is released and the tundish slag is filled in the sample. The rectangular samples and slag invaded samples were respectively fired into an electric furnace at a high temperature, 1 550 °C and 3 hours. The physical and chemical indexes of the samples after drying and burning are shown in Table 3, and the static slag invaded samples are shown in the photos in Figure 2, and the chemical analysis of test slag is shown in the Table 4.

By analyzing the data in Table 3, it can be concluded that flexural strength: due to the same binder, different grades of magnesia raw materials have no effect on the flexural strength of formula 1, formula 2 and formula 3, and the strength index can meet the use requirements. Volume density: the particle density of different magnesia raw materials is different. Formula 1, formula 2 and formula 3 have different volume density. Line gradient after burn: for samples made from different magnesia raw materials, the rate of change of firing line for samples in formula 1, 2 and 3 ranges from -1,25 % to -1,68 %. The results show that the three formulations can meet the requirement of tundish disassembly. It can be seen from Table 4 and Figure 2 that: comparison of the slag invaded samples after firing, anti-slag erosion and anti-slag permeability 2# formula >1# formula >3# formula.

IMPROVE THE WORKING LIFE OF TUNDISH LINING

In the process of casting steel, a certain amount of coating agent should be added to each can of steel. As the amount of coating agent increases, the amount of slag formed in tundish increases and the slag layer thickens accordingly, which intensifies the erosion of resistant material of slag line. Especially when the content of F, Mn and other harmful components in tundish slag is high, the erosion of slag line is more serious. The basicity of tundish slag fluctuates within a certain range in the

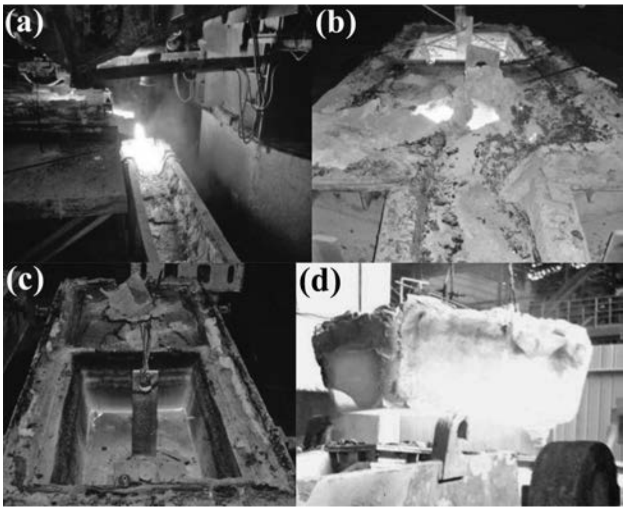

Figure 3 Tundish working diagram
(a) overflow groove, (b) slagging
(c)after discharge, (d) normal disintegration

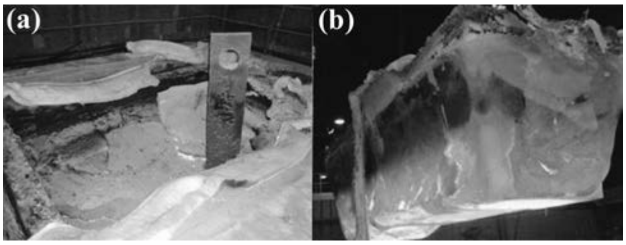

Figure 4 Tundish working slag line
(a) slag line erosion
(b) post-disintegration sintering

same casting process due to the different types of steel and the variation of coating agent formulations from different manufacturers. When the alkalinity of slag is smaller, the erosion of tundish lining is more serious. The slag discharge operation of tundra is stipulated as follows : (1) the slag thickness in the casting process shall not exceed 200 mm; (2) When the thickness of the middle enveloping slag layer reaches 200 mm, the middle enveloping slag is discharged from the bottom; (3) Control the amount of overlay. After slag control operation, the thickness of slag layer is reduced, the corrosion of steel slag on slag line part of tunic lining is reduced, and the service life of tunic lining is improved. Picture of tundish after normal slag discharge is shown in Figure 3.

The slag under ladle is one of the main reasons for the serious erosion of tundish slag line. Due to the addition of fluorite and other refining agents in the refining process of molten steel, the mineral phase with low melting point is formed, and the alkalinity and viscosity of slag are reduced, which cause serious erosion to the working lining of mag- nesium tundish. To improve the working life of tunic lining, the slag quantity of ladle must be controlled. Pictures of the tunic working slag line after erosion are shown in Figure 4.

Dry material is a kind of product with low density and strength. The corrosion of tundish lining will be aggravated by the fluctuation of liquid steel level and the

Table 5 **Experimental results**

No.	Steel type	Casting number	Casting time/h
1#	Al	32	17,28
2#	Al	30	17,1
3#	Al	32	16,4
4#	Al	32	16,1
5#	Al	26	17,5
6#	Al	26	15
7#	Al	30	14,3
8#	Al	31	18,2

change of liquid steel flow field. Therefore, the liquid level should be appropriately increased in advance during tank changing to slow down the fluctuation of the liquid level and keep the liquid level as stable as possible. Reduce the damage caused by liquid level fluctuation to tunic lining. The slag line of tundish is the part with the most severe service conditions. In order to alleviate the erosion of the slag line part, the liquid level of slag line can be adjusted timely in the casting process, which can alleviate the erosion of steel slag on the same part of the slag line for a long time. Adding calcium and iron powder in pouring steel is one of the methods to prevent the flocculation flow at the nozzle during continuous casting. However, when calcium and iron powder is added, the instantaneous temperature rises sharply, the molten steel boils, and the local temperature is too high, which is prone to local erosion or penetration of the slag line, and the sintering of the working lining in the casting steel area is unfavorable for the use of the tundish working lining. Therefore, under the premise of ensuring the normal casting of steel, the amount of calcium and iron powder should be as little as possible.

The continuous casting tundish was tested for 8 bags in total, and the effect was good. The working lining life of tundish was 16,5 hours on average, and the average number of continuous casting cans was 29,9. The maximum service life is 18,2 hours and the maximum number of continuous pouring cans is 32 cans. The test results are shown in Table 5.

CONCLUSION

By analyzing the causes of tundish lining damage, optimizing the formula and adjusting the continuous casting process, the service life of tundish lining can be improved. The main formula and scheme are as follows: firstly, different schemes are adopted to optimize the formula respectively in the water mouth area, casting steel area and the bottom of the tundish for partial construction, so as to realize balanced corrosion loss of tundish working lining, reduce the consumption of steel resistant material per ton, and improve the working life of tundish working lining. Secondly, adjusting the slag discharge operation, reducing the amount of slag under the ladle, controlling the liquid level fluctuation of molten steel and adjusting the liquid level of slag line are effective measures to improve the service life of tunic lining. By adopting the above technical scheme, the tundish lining service life has been greatly improved, from 13,5 hours to more than 16 hours, which has been popularized.

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Note: The responsible translator for English language is Y. X. Chen, Anshan, China.