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Flux Application in Steel-Teeming Ladles of Conventional Power Plant at JSC "Azovstal"

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The technology of adding high-magnesia MgO-CaO flux of ФОМИ grade produced by Magnezit Group into slag in steel-teeming ladles was introduced at the conventional power plant at JSC "Azovstal". This increased the life of oxide-carbon refractory of both lining of the slag belt and the walls. The slag in the steel-teeming ladle preserved its desulfurizing ability.

Keywords: HIGH MAGNESIA FLUX, LINING, STEEL-TEEMING LADLE

Introduction

Forming of wall accretion layer on the surface of the lining working layer of steel-teeming ladle is carried out due to the solidification of molten slag [1, 2]. In the slag belt one way or another, the conditions of intense heat are created, such as in the control layer of the lining of periclase-chromite refractory is placed and heat insulator is not installed in order to slow down the reaction of slag with the refractory. In the wall, on the contrary, the challenge of insulation, for example, pyrophyllite (semisiliceous) refractory is used in the control layer, and this layer ajoint with the metal case 5-12 mm thick heat insulator is placed. It also limits the temperature of the metal case to 280-320 ° C, what eliminates its contraction, even when worn working lining slows the cooling of the metal [3].

For wall accretion on the walls of steel-teeming ladles it is advisable to maintain the content of MgO in the slag at the level of 9-10%. Wall accretion blocks access of oxygen to the refractory, slows the oxidation of periclase-chromite refractory in the empty ladle, slows the cooling of the lining and decreases the rate of temperature rise while filling the ladle with metal.

Results and Discussion

The experiments [1] showed efficiency of high-magnesia flux ФОМИ (variant Dalslag PL66), containing, %:> 66 MgO, 12-22 CaO, 4-8 Fe_2O_3, 5 SiO_2 and Al_2O_3, and less than 0,01 S compared to the flux containing up to 4% CaO, but which has a mass loss during ignition up to 45%. Mostly calcium ferrites and less frequently calcium aluminum iron silicates are ceramic bonds. The total content of ferrites and silicates is usually not more than 9%, but it is enough in case of contact with metal to be quickly destroyed. Flux is added to the ladle when it is filled to 1/3-2/3 of its volume, what contributes to the homogenization of the covering slag in the ladle at the time of submission of the metal for the installation of ladle furnace.

The advanced technology of flux application was worked out at the conventional power plant at JSC "Azovstal" under the following conditions:

- temperature of the ladle lining before tapping - 600-750 ° C;
- temperature of the metal during tapping from the converter - 1630-1700 ° C;
- temperature of the metal in ladle furnace (LF) - 1530-1545 ° C;
- metal rate processed at the ladle vacuumizing facility - 40%;
- residence time of metal in the ladle from tapping from the converter till delivery to the CCM - 2.5-3.5 h;
- the average time of steel casting in CCM - 1.3 h;
- Average ladle turnover - 3,35 heats per day.

Laying of the steel-teeming ladle working lining was performed with the help of oxide-carbon refractories:

- slag belt with periclase-chromite products based on smelted periclase with 12-14% of graphite, 3-4% apparent porosity, compressive resistance 40-50 N/mm2, the course thickness 200 mm;

- underslag belt with periclase-chromite products based on smelted periclase with 10-12% of graphite, 5-6% apparent porosity, compressive resistance 40-50 N/mm^2, the course thickness 170 mm;

- periclase-aluminum-chromite walls based on smelted corundum and periclase with ~ 8% graphite, 5-6% apparent porosity, compressive resistance 40-50 N/mm^2, the course thickness 170 mm.

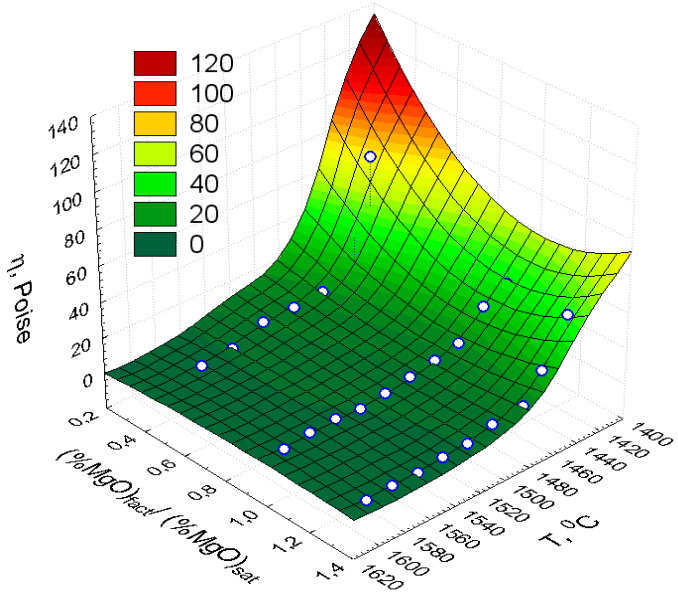

Figure 1. The dependence of the dynamic viscosity of slag on the ratio of (% MgO)$_{factual}$/ (% MgO)$_{saturation}$ and temperature

Wear and tear of carbon-bearing refractories undergoes as the oxidation of carbon component in the process of drying and heating of the lining (oxide-carbon component begins to oxidize, even at 350°C, the temperature of the beginning of the graphite oxidation does not exceed 560°C), oxidation of carbon with slag and steel oxygen . When the porosity of oxide-carbon refractory is 4-6%, its porosity after heating the ladle to 1000 ° C is 7-10% and after the oxidation 10-12% of carbon exceeds 30%. The slag penetrates into the layer of carbon-free refractory and reacts with its oxide components by dissolving the floured oxide part and forming low-melting multiple phases. The presence of calcium fluoride in slag accelerates the corrosion of refractory material. According to [4] a sample of periclase refractory having a fairly tight grain diameter of 20 mm, loses, for example, during immersion in the slag containing CaF2 from 0.6 to 2.2 mm in diameter within 15 min. During argon blow periclase grains are washed out of the refractory.

The addition of magnesium flux into the ladle increases the viscosity of the slag. In this case it will lose its assimilative towards the oxide inclusions and sulfate-reducing capacity and may harden before discharging the metal from the ladle. Upon reaching the saturation concentration of MgO the dissolution of MgO from the lining decreases.

Figure 1 shows the variation of dynamic viscosity of the slag because of changing of temperature and degree of saturation of the slag magnesia (% MgO)$_{factual}$/ (% MgO) $_{saturation.}$

There are two techniques of targeting desulfurizing slag at the conventional power plant at JSC "Azovstal" [5]: by adding lime and calcium fluoride and for a number of high-quality brands of steel - refinery slag containing (%) 56,5-58 CaO; 12-13 SiO_2; 15-16 Al_2O_3; 7,0-7,3 Na_2O; 0,1 S; 4,4-4,7 % F with fusion temperature 1255-1270 °C. It was established that the refinery slag quickly forms with high-magnesia flux homogeneous free-running slag.

Since 2008, at the conventional power plant at JSC "Azovstal" a technology of using high-magnesia flux was developed to improve the stability of 350-ton steel-teeming ladles lining in conditions of metal processing in LF. Flux ФОМИ (Dalslag P66 or Dalslag PL66) is supplied in the form of spherical pellets of size 4-40 mm (**Figure 2**), fractions less than 8 mm do not exceed 10%, what provides them by gravity along the liners.

Slag composition with the use of flux ФОМИ

and without it is shown in **Table 1**.

Table 1. Slag analysis with the use of flux ФОМИ and without it

	Without the use of flux, (average value from 3 test samples), %				With the use of flux (average value from 3 test samples), %			
	MgO	CaO	FeO	SiO_2	MgO	CaO	FeO	SiO_2
Min	2,8	44	0,82	12	3,5	42	0,43	9
Max	5,3	58	4,20	21	18	58	4,74	19
Average	4,5	49	2,7	17	11	48	2,6	12,9

It was established that 250-500 kg of flux should be added during the period of filling the steel-teeming ladle with metal from 1/3 to 2/3 of its height. Measures of slag quantity reduction in the steel-teeming ladle were taken by undermining the converter while slag appearing at the end of tapping.

During the process of development of the technology of flux ФОМИ usage the comparative analysis of the metal desulphurization degree in the steel-teeming ladle with the use of flux and without it under the same conditions.

The metal desulphurization degree in the steel-teeming ladle is shown in **Table 2**.

Table 2. Metal desulphurization degree with the use of flux and without it

Degree	Metal desulphurization degree in the steel-teeming ladle							
	From tapping till the processing out of furnace				From tapping till the middle of casting			
	Experimental with ФОМИ		Comparative		Experimental with ФОМИ		Comparative	
For melts with	[C] content < 0,05%	[C] content ≥ 0,05%	[C] content < 0,05%	[C] content ≥ 0,05%	[C] content < 0,05%	[C] content ≥ 0,05%	[C] content < 0,05%	[C] content ≥ 0,05%
Min	3	7	7	12	13	33	20	46
Max	44	62	73	81	81	86	75	77
Average	28	40,6	33,4	34,4	56,5	66,4	50,6	61

It was established that at the stage from tapping from the converter till the processing out of furnace, there was a degree of desulphurization of the metal in average 28% on experimental melts with carbon content in the metal before tapping of less than 0.05% and it was 5.4% lower than on the comparative melts. The degree of desulphurization of the metal was in average 40.6% on the melts with carbon content in the metal before tapping of 0.05% or more and it was 6.2% higher than comparative melts. At the stage of tapping from the converter to the middle of casting the average degree of desulphurization of the metal on experimental melts regardless of carbon content in the metal before the tapping was 5,4-5,9% higher than for the comparative ones, and it was 56,5-66, 4%.

Figure 2. The appearance of flux pellets ФОМИ

According to the results on the effectiveness of magnesium flux in a pilot-scale, it was decided to move to its systematic use in all brands of steel produced in the workshop. With an average ladles turnover of 3.35 heat per day, average temperature of the metal during tapping 1654°C the melting rate, on which the addition of flux was performed, was 88.7%. According to the results of operation during the period prior to the use of flux and the period during which the flux was added (more than 100 ladles were analyzed), the analysis of the stability of the steel-teeming ladle lining showed that:

- the share of ladles with a double replacement of refractories in the slag belt zone was reduced from 94 to 62%;
- the average resistance of the working layer of slag belt lining increased from 31.3 to 37 heats;
- the average resistance of the working layer of steel-teeming ladles lining increased from 74.8 to 77.6 heats.

Conclusions

The technology for adjusting the composition of the slag in the steel-teeming ladle with the use of magnesia flux containing not less than 66% MgO and 12-22% CaO was developed at the conventional power plant at JSC "Azovstal".Adding of in average 242 kg/heats magnesium flux increases the content of MgO in the slag to 9-10%, what increases the resistance of periclase-chromite refractories in the slag belt lining of steel-teeming ladles while maintaining the degree of desulphurization of the metal out of furnace.

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Использование флюса в сталеразливочных ковшах конвертерного цеха ОАО «МК «Азовсталь»

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В конвертерном цехе ОАО «МК «Азовсталь» внедрена технология присадки в шлак в сталеразливочном ковше высокомагнезиального MgO-CaO-флюса марки ФОМИ производства ОАО «Группа Магнезит». Это повысило стойкость оксидоуглеродистых огнеупоров как в футеровке шлакового пояса, так и стен. Шлак в сталеразливочном ковше сохранил десульфурирующую способность.