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RESEARCH AND IMPROVEMENT OF THE PRODUCTION TECHNOLOGY OF HIGH-MANGANESE STEEL 110G13L FOR RAILWAY FROGS

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Abstract

This article is devoted to the method of calculating the joint complex deoxidation of steel grade 110G13L. Steel grade 110G13L was chosen as the metal under study. The industrial demand for high manganese steel castings is constantly growing. At the same time, the requirements for them are increasing, and the prices for manganese-containing alloying materials tend to increase continuously. Therefore, both improving the quality indicators of castings from high-manganese steels and reducing the cost of their manufacture are relevant. Such a complex problem can be solved in

different ways. One of them is the improvement of the technology of deoxidation and modification of steel.

Keywords: 110G13L **;** complex deoxidation **;** oxygen **; non-metallic inclusions; modifier; silicon;** aluminum.

Introduction

High-manganese steels containing 8.5-15% manganese, due to their high wear resistance under impact loads, have for many years remained an indispensable structural material for the manufacture of replaceable parts of machines and equipment in machine-building, mining, metallurgical, railway and other industries. These steels are used to make linings for vortex and ball mills, tram and railway crosses and turnouts, caterpillar tracks, sprockets, excavator bucket teeth and other parts.

The technology for smelting high manganese steels also necessarily includes final - deoxidation and modification of the melt in the ladle. As a rule, aluminum and titanium are used for this. It is important to ensure the optimal residual content of these elements. This is especially important for aluminium, as high manganese steels are prone to nitrogen saturation. With a combination of a high content of nitrogen and aluminum in these steels, crystallization film nitrides AlN are formed , which significantly reduce the mechanical properties and also increase their tendency to cracking. The instability of aluminum assimilation makes it difficult to prevent this process . Therefore, researchers have attempted to replace aluminum ingots with another deoxidizer that would provide more stable absorption of aluminum. Among other things, ferrosilicoaluminum (FeSiAl) was considered as an alternative. However, the wide use of FeSiAl was hampered by its insufficient knowledge, in particular, the lack of reliable data on the phase structure, on the optimal consumption, on the degree of aluminum assimilation, and on the non-metallic inclusion formed in this process. There are also no data on the effectiveness of its use in combination with titanium.

Methods

Investigation of the efficiency of replacing the modifier (Al+Ti) by (FeSi45Al15+ Ti) in the processing of steel 110G13L, the oxygen content was determined using a fractional gas analyzer.

To study the processes of joint deoxidation and modification of high -manganese steel 110G13L in (Al + Ti) and (FeSi45Al15+Ti) a series of laboratory experiments was

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performed. Melting was carried out in a Tamman resistance furnace, the scheme of the furnace is shown in Fig. 1. The design of the furnace made it possible to add additives, take samples and measure the temperature without violating the tightness of the installation. The temperature is measured with a thermocouple type BP 5/20, the hot junction of which is placed under the bottom of the crucible. The temperature is measured with an accuracy of ±15 K.

The weight of the mixture averaged 310 g. The metal was melted in an alundum crucible, the material of which is chosen depending on the metal under study, the temperature of the experiment, and the deoxidizer. Pig aluminum (Al + Ti) on ferrosilicoaluminum (FeSi45Al15+ Ti) was fed through a quartz tube from above into the melt in the form of finely crushed pieces. Heating and melting of the mixture (-60 min) was carried out in the environment Ar . After melting the metal in the furnace, a pure argon environment was created and a preliminary sample was taken. The sample was sucked from the melt with a quartz tube with an inner diameter of 7 mm. The mass of the first sample was about 20 g. The sample was cooled for -30 s in an argon atmosphere, then in air. After sampling, during the melting of the charge, aluminum and titanium (Al + Ti) were added, at a given content, exposure was carried out for 10-15 minutes to stabilize the temperature after the addition. After exposure, a second sample was taken. The second melting was carried out similarly, in contrast to the selection of the first sample, ferrosilicoaluminum and titanium (FeSi45Al15 + Ti) were added during the melting of the charge.

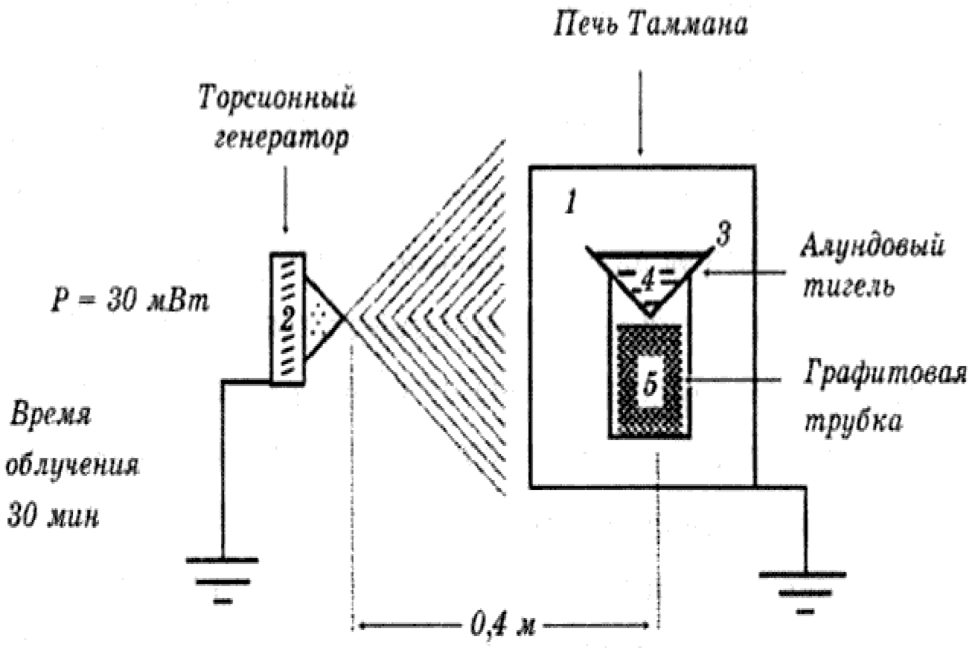

Figure 1 - Tamman Resistance Furnace

Table 1 - Chemical composition of steel 110G13L

GOST	Mass fraction of the element, %						
	C	M n	Si	S	R	C r	N i
				no more			
7370-98	1.00- 1.30	11.5- 16.5	0.30-0.90	0.02	0.09	-	-

The calculation of the charge material was carried out in the program Excel taking into account the coefficients of assimilation of elements. The calculation result is shown in Table 2.

Table 2 - Consumption of charge materials for melting high-manganese steel 110G13L

charge material	Weight, g	C	Mn	Si	S	P
(Steel 10)	250	0.525	1.175	0.05	0.125	0.15
FeMn70	35	2.45	20.825	2.1	0.007	0
FeMn95	25	0.05	20.1875	0.45	0.0125	0.0175
Total, g	310.0	3.03	42.19	2.60	0.14	0.17
Total, %	100	0.98	13.61	0.84	0.05	0.05

After sampling 1, the mass of metal is 290 g. Let's calculate the amount of aluminum that needs to be introduced. Aluminum is found in an amount of 0.7 kg / t, then 0.7x0.290 =0.203 g. Sponge titanium consumption is 1.6 kg/t, then 1.6x0.290=0.464 g. In the second heat, ferrosilicoaluminum FeSi45Al15 is used in the amount of 3.5 kg / t, then 3.5x0.290 = 1.015 g.

Results and Discussion

When determining the chemical composition of 110G13L, the content of elements (M n , Si , P, C r , A1, T i) was determined on an X-ray spectrometer SPM-25 by the X-ray fluorescence method. The chemical composition is shown in tables 3 and 4

Table 3 - Chemical composition of steel 110G13L, modification in (Al + Ti)

Elements	C	Si	M n	P	C r	Mo	Ni	C u	A1
content, mass, %	1.06	0.644	12.86	0.052	0.119	<0.010	0.022	0.024	0.018

Mg	Co	Nb	T i	V	W	Fe
0.011	0.011	<0.0050	0.084	0.022	0.100	84.24

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Table 4 - Chemical composition of steel 110G13L, modification in (FeSi45Al15 + Ti)

Elements	C	Si	M n	P	C r	Mo	Ni	C u	A1
content, mass, %	1.062	0.654	12.66	0.051	0.119	<0.010	0.022	0.024	0.024

Mg	Co	Nb	T i	V	W	Fe
0.011	0.011	<0.0050	0.094	0.022	<0.100	85.24

Determination of the oxygen content in samples of high -manganese steel 110G13L was carried out by the method of reductive melting in an inert gas flow on a TS-600 analyzer from L ESO.

Analysis of the results of the experiment **.** The oxygen content was determined in samples of high -manganese steel 110G13L taken before deoxidation (sample 1) and after deoxidation (sample 2).

The total oxygen content in high -manganese steel 110G13L before deoxidation (sample 1) is 0.00332-0.00336%, but after deoxidation (sample 2) it decreases to 0.00125-0.00188%. At the same time, the treatment of high -manganese steel 110G13L with an experimental technology deoxidizer provides a third less oxygen content (table 4).

Table 5 - Oxygen content in high -manganese steel 110G13L when treated with (Al + Ti) and (FeSiAl + Ti) complexes.

№ melting	Steel processing option	Sampling location	Oxygen content Σ [O], %
1	Complex treatment (0.7 kg/t Al + 1.6 kg/t Ti)	Before processing	0.00322
		After processing	0.00188
2	Complex treatment (3.5 kg/t FeSiAl + 1.6 kg/t Ti)	Before processing	0.00336
		After processing	0.00125

The measurement of oxygen activity shows (Table 5) that with the same oxygen activity in high -manganese steel 110G13L, the treatment of the melt with the complex **(**FeSiAl + Ti) provides a deeper deoxidation than in the case of its treatment with the complex (Al + Ti).

Residual content of Al and Ti . We also studied the residual content and the degree of assimilation of aluminum and titanium in the (Al + Ti) and (FeSiAl + Ti) versions of the deoxidation of high -manganese steel 110G13L. When processing high -manganese steel 110G13L by the complex (Al + Ti), the concentration of residual aluminum is 0.018%, and the degree of assimilation is 18.66%. When processing high

-manganese steel 110G13L by the complex (FeSiAl + Ti), the content of residual aluminum is 0.024%, the degree of assimilation is -44.58%.

Figure 2 shows the comparative content of residual aluminum in high -manganese steel 110G13L treated with the (Al + Ti) and (FeSiAl + Ti) complex.

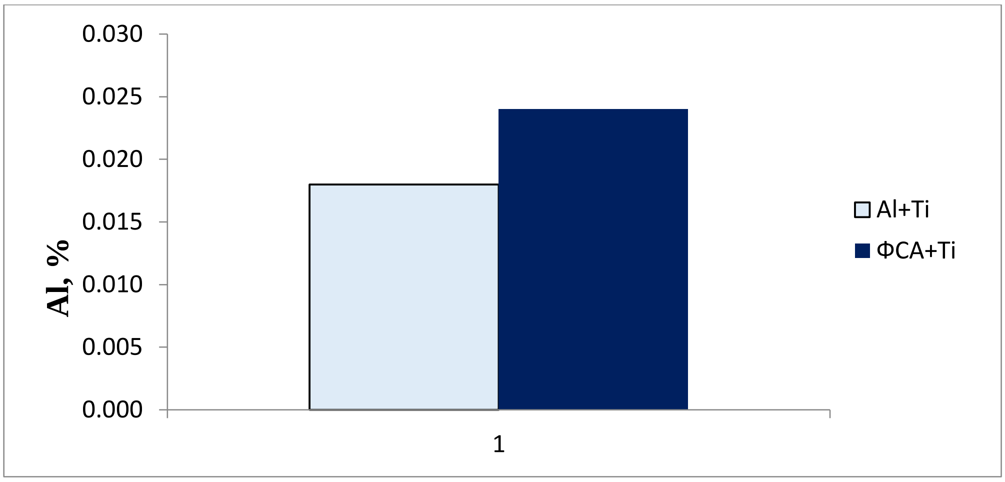

Figure 2 - Residual content of aluminum in high -manganese steel 110G13L, treated with a complex (Al + Ti) and (FeSiAl + Ti).

An analysis of the titanium content in the melts treated with the (Al + Ti) and (FeSiAl + Ti) complex showed (Figure 3) that in the case of the use of the FeSiAl, the residual titanium content was 0.094% compared to 0.084% when titanium was added together with aluminum, titanium waste 39.9% and 46.3% respectively. This indicates that at the same consumption of titanium sponge, the degree of assimilation of titanium increases from 53.7% to 60.1% in the case of its introduction together with FeSiAl.

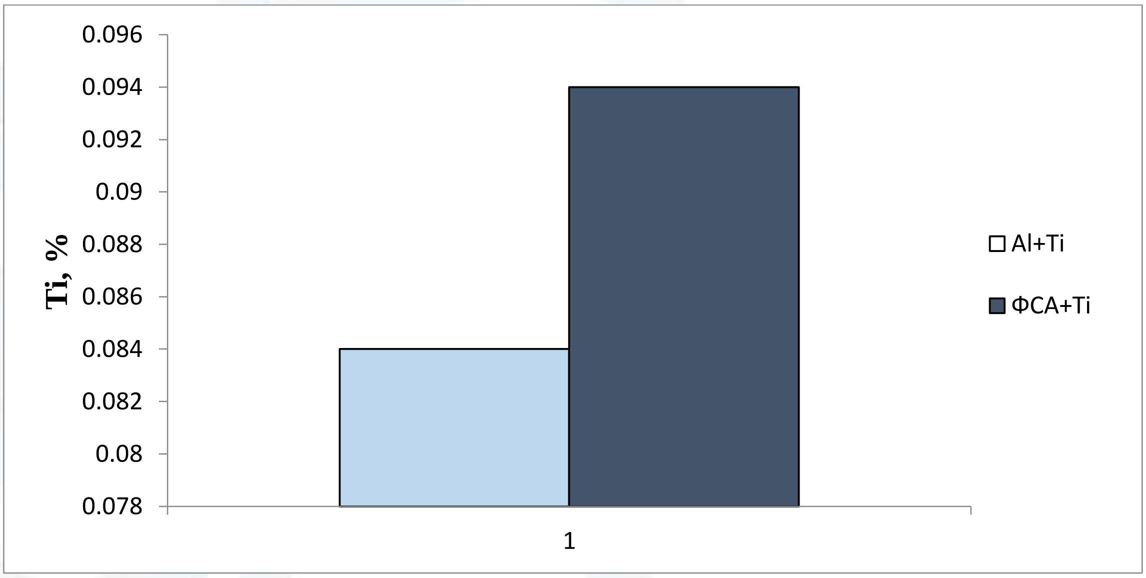

Figure 3 - Residual content of titanium in high -manganese steel 110G13L, treated with a complex (Al + Ti) and (FeSiAl + Ti).

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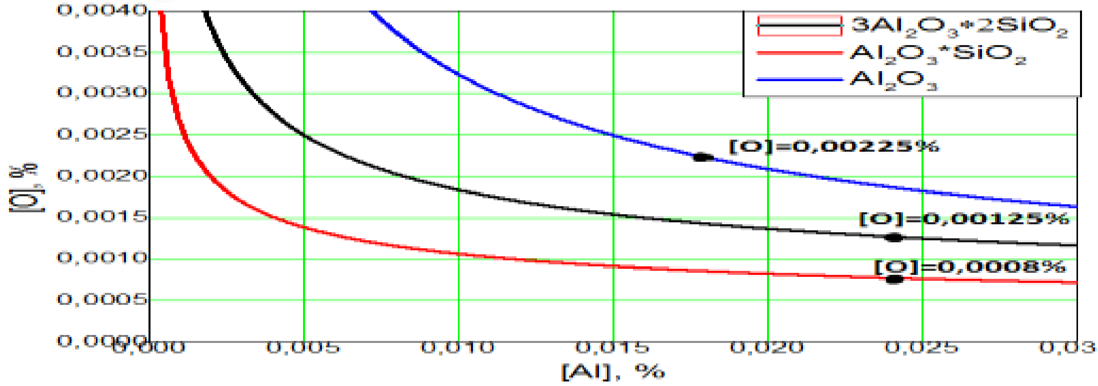

Figure 4 - Dependences of the solubility of oxygen in the melt composition of steel 110G13L at a temperature of 1873 K on the concentration of silicon and aluminum: ● – experimental data;

Table 6 - The oxygen content in steel 110G13L experimental and calculated

Steel processing option	Σ [O] $_{experiment}$, %	Σ [O] $_{estimated}$, % масс		$\Delta\Sigma$[O], %
Complex treatment (0.7 kg/t Al + 1.6 kg/t Ti)	0,00188	0,00225		0,00037
Complex processing (3.5 kg/t FeSiAl + 1.6 kg/t Ti)	0,00125	$3Al_2O_3 \cdot 2SiO_2$	0,00125	0
		$Al_2O_3 \cdot SiO_2$	0,0008	0,00045

An assessment of the difference between the calculated and experimental results in terms of Δ [O] showed that Δ [O] when treated with the complex (0.7 kg/t Al + 1.6 kg/t Ti) was 3.7 ppm , and when treated with the complex (3.5 kg/t FeSiAl + 1.6 kg/t Ti) was 4.5 ppm .

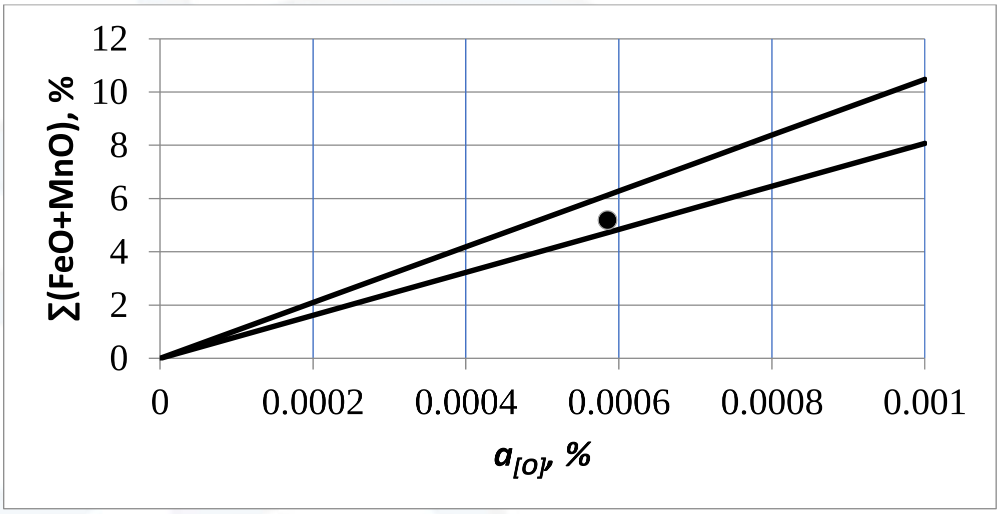

Figure 5 - Influence of oxygen activity in steel on Σ (FeO + MnO) in slag at different content in of manganese 1 and 2 - content [M n] in steel 11.5 and 15.0%, respectively, ● – experimental data;

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Determine the activity of oxygen . With an oxygen content of 0.00336% before treatment with the complex (FeSiAl + T i) , $a_{[O]}$ =0.000585%, putting this value in Fig. 6, we get ∑(FeO + MnO)=5.18%.

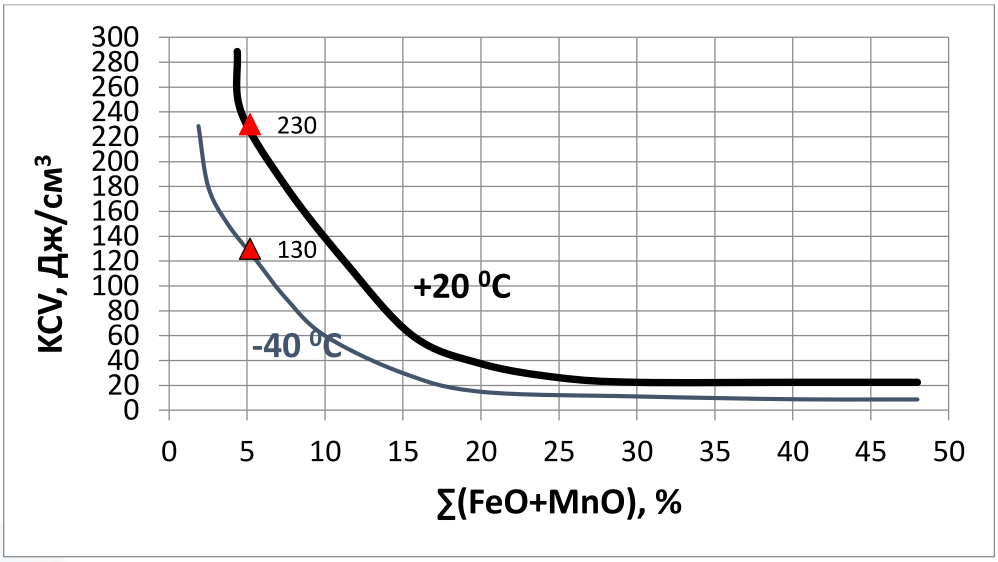

Figure 6 - Influence of the content in the slag ∑ (FeO + MnO) on the impact strength of steel 110G13L

Conclusions

For railway frogs, the impact strength should exceed 200 J/sm³ , for our case, when the total content of (FeO) and (MnO)=5.18% at 20° C , the impact strength is 230 J/ sm³ .

The result of the experiment showed that the use of ferrosilicoaluminum together with titanium (FeSiAl + Ti) in the processing of liquid steel 110G13L is more efficient than the use of secondary aluminum with titanium (Al + Ti), which is confirmed by a large (1.5 times) decrease in the oxygen content during deoxidation , as well as better absorption of aluminum (by 2.4 times) and titanium (by 12%).

The implementation of the developed technological recommendations for testing at the LMZ plant is expected to produce high-quality castings without defects, with a high and stable level of mechanical properties and to increase the efficiency of ladle processing and to obtain an economic effect by reducing the consumption of deoxidizer and modifier.

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