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THE RESEARCH OF MODIFICATION PROCESS OF STEEL HADFIELD INTEGRATED ALLOY FERROALUMISILICOCALCIUM (Fe-Al-Si-Ca/FASC)

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There is article discusses the process of modification of high-manganese steel, Hadfield, which will significantly increase the yield of the casting at the stage of melting and casting the steel. The steel modification performed integrated alloy FASC (ferroalumisilicocalcium) in an amount of 03 - 0,5% by weight of the metal. The integrated alloy unlike traditional methods of modification leads to globalizatsii and purification of steel from nonmetallic inclusions and for grinding grains of austenite, thereby greatly increases its mechanical properties.

Key words: High-manganese steel, modification, ferroalumisilicocalcium (FASC), structure, chemical composition

INTRODUCTION

Increase of requirements to quality of products, working in the mining industry requires the improvement of service characteristics of alloys, which are made of these products. The bulk of such equipment is operating in conditions of abrasive and impact - abrasive wear (lining to ball mills “cheeks” grinders, “the teeth” of the excavators). The world experience shows, codetel mining and metallurgical equipment in large numbers are cast from steel 110G13L (Russian grade). This is due to unique properties of high-manganese austenitic steel 110G13L type, in particular high-impedance surfaces in a deformed state abrasive wear in combination with high ductility and toughness [1]. The deformations at 50 – 60 % the hardness of steel 110G13L increases in 2,0 – 2,5 times caused considerable lattice distortions, crushing blocks of the grain structure, work hardening and the formation of a martensite structure in the contact layers [1].

The working conditions of components made of steel 110G13L, to its chemical composition (GOST standard 977-88), as well as to methods of production have different requirements. 80 % of products from wear-resistant steel 110G13L get in the casting process by means of remelting the metal charge, as the 110G13L steel is not welded. All materials used for melting, should be known the chemical composition and to have the certificates confirming compliance with material regulatory and technical documentation. However, the wide limits of concentrations of carbon and manganese under equal conditions does not guarantee constancy of properties, even for parts of one and the same purpose.

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It should be recognized that the traditional methods of improving properties of steel by their composition is almost exhausted. Mainly material properties depend on the structure of the steel at the macro level. The solution is the development of technology an effective way of modifying high-manganese steel, new complex alloys, crushing, thereby the grain structure and reducing the number of nonmetallic inclusions, all this contributes to the quality Kazakhstan machine-building metal products [2].

EXPERIMENTAL PART

Equipment and tools

In the research process experienced melting to obtain high-manganese steels was held on various options for the modification in high temperature furnace Tamman, in corundum crucibles. Maximum working temperature 2 000 °C, the mass of the studied materials up to 400 g, has the ability to purge inert gases.

Metallographic analysis of the obtained samples of the original steel in the cast state before heat treatment. The samples are cut with a cutting machine Lobotom-3 - high-precision cutting machine, designed for accurate strain-free cutting of metals with the hardness from 30 to 2 000 HV. The cutting machine allows to obtain a cut having a smooth, minimally deformed surface. Abrasive wet cutting minimises damage to the surface, which facilitates and accelerates further sample preparation Metallographic sections prepared according to standard methods, using a grinding and polishing machine - Tegra Pol – Tegra Force of the company Struers, designed for high quality automated grinding and polishing. The machine is used with the use of grinding discs and polishing cloths magnetic fixation on MD-System.

The machine allows materialographic preparation of materials with hardness 30 – 2 000 HV.

Further studies of thin sections were performed on a raster electronic microscope Tescan Vega is designed to study the surface structure of materials in the range of magnifications of 4× and 500 000×, obtaining a volumetric image of the structure of thin sections and studies of fractures of metals and alloys, determination of particle size, determine the causes of failure, predict the strength and performance of various materials. Resolution 3,0 nm (at 30 kV); Increase from 12× to 1 000 000×; the Diameter of the specimen chamber 230 mm.

MATERIALS AND METHODS

On the basis of studies of modification of high-manganese steel was developed by the technology of its smelting, which was carried out on the basis of the laboratory "Metallurgy of steel" Chemical-metallurgical Institute named Zh. Abishev.

As charge used:

- the return of foundry steel 110G13L GOST 977-88;
- scrap and waste B steel 110G13L GOST 2787-75; scrap steel 1A, 2A GOST 2787-75 .

As alloying materials used deoxidizers and modifiers:

- low carbon ferromanganese brand FeMn78 class AGOST 4755-91;
- the grades of ferrosilicon FS65 GOST 1415-93;
- aluminum brand AV GOST 295-79;
- calcium-silicon brand SK30 GOST 4762-72;
- coke fines THAT 14-7-115-89.

The chemical composition of deoxidizers, is listed in Table 1

Table 1 **Chemical composition of deoxidizers**

Ferroalloy / wt , %								
FMn 78	C	Si	Mn	Al	Ca	S	P	Fe
	1,13	1,40	78,0	-	-	0,03	0,4	19,4
FS 65	-	62,0	-	2,0	-	0,03	0,05	35,92
AB 97	-	-	-	86,0	-	-	-	-
SK 30	0,5	60,0	-	2,0	30,0	-	0,04	7,460

As slag-forming materials used:

- the limestone dry lump OST 1464-80 and in separate experiments, fresh burnt lime;
- fluorspar concentrate GOST 7618-83.

Waste and foundry returns steel 110G13L carefully cleansed from adhering thereto forming a mixture, as applied in the smelting of waste return and with great penetration makes it much harder for the formation of a white slag, and in an industrial environment, this will adversely affect the durability of the hearth furnace and slopes [3].

All alloying materials and deoxidizers, except aluminum, which was pressively of the liquid metal, is calcined at a temperature of 600 - 800 °C for 2 - 3 hours. Aluminum before applying dry.

Powders of ferroalloys (ferrosilicon, calcium-silicon), which is used for deoxidation of slag in the recovery period of melting, sifted through a sieve with cells of 2 x 2 mm. Determined the moisture content in the powders was 0,3 %.

Metallurgical limestone was used with a mass fraction of calcium oxide (CaO) 55 % and moisture 0,5 per cent. Lime is used fresh firing which was stored in a desiccator. Fluorite concentrate was dried before the melting at a temperature of 300 °C for one hour.

When calculating the charge and alloying materials take into account the absorption coefficients of the elements (Table 2).

Table 2 **The coefficient of absorption of elements**

Element	The coefficient of absorption of elements			
	during the melting from scrap steel		when enter the liquid metal (in the furnace or in the ladle)	
Carbon	0,80-0,95	-	0,80 - 0,95	-
Silicon	0,30 - 0,50	0,70- 0,90	0,30 - 0,50	0,70 - 0,90
Manganese	0,50 - 0,70	0,70-0,90	0,50 - 0,70	0,70 - 0,90
Chrome	0,80 - 0,95	0,80 - 0,95	0,80 - 0,95	0,80 - 0,95
Calcium	0,98	-	0,98	-
Aluminum	0,00	0,0 - 0,50	0,00	0,0 - 0,50

During the steel smelting (melting method) metallizable was completely out of waste and return foundry steel 110G13L. In order to avoid high carbon content in the metal used scrap carbon steel brand 1A, 2A GOST 2787-75 in the amount of 10 % of the total weight of the charge.

This, the composition of the charge in the smelting of steel 110G13L (by remelting) received:

- the return of foundry waste and steel 110G13L – 90 %; scrap carbon steel brand 1A, 2A GOST 2787-75 – 10 %.

To obtain the necessary mass fraction of carbon (according to the standard for steel 110G13L) of finished steel was added screenings of Corsica.

In order to save ferromanganese and produce quality metal calculation led to the content in the finished steel is 12,5 – 13,5 per cent of manganese. In the calculation of the charge took into account that the pernicious elements in the metal after it is melted, when melting steel 110G13L is 7 %, and nonrecoverable losses – 2 %.

All charge and alloying materials required for melting, pre-weighed according to the calculation. The loading of the charge carried out before turning on the oven. The charge was pressively screening of Corsica in the required quantities in accordance with the calculation for carburizing metal, limestone (or lime) in an amount of 1,5 – 2,0 % by weight of the metal.

The period of melting was carried out at the maximum power by switching the transformer on the highest step voltage. After complete melting of the charge was sampled for chemical analysis for determination of carbon, manganese, silicon, phosphorus and sulfur and metallographic tests. At a temperature of as entered the estimated amount of ferromanganese and ferrosilicon.

The final deoxidation of steel with aluminium carried out in the amount of 0,05 - 0,06 % (0,5 - 0,6 kg/t) by weight of the metal.

For globularization and purification of steel from nonmetallic inclusions and for grinding the grain of austenite, produced the modification of metal ferroalumisilicocalcium (FASC) in an amount of 0,5 % by weight of metal, with chemical composition %: silica 45 ÷ 50 %; aluminum 15 ÷ 20 %; calcium 13 ÷ 16%; Fe.

The temperature of the metal on the range of 1 460 °C - 1 480 °C. Produced by this technology, the metal was poured in a steel mold for metallographic studies.

RESULTS AND DISCUSSION

In the process of experimental research, was obtained steel, the chemical composition of which is given in Table 3.

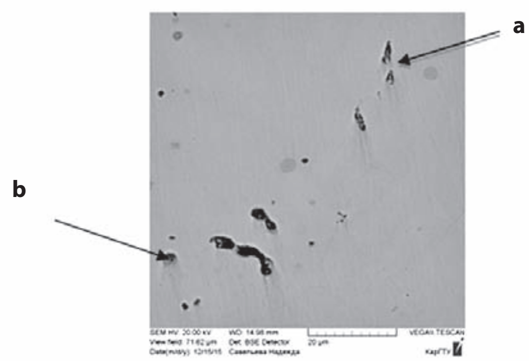
Table 3 **Chemical composition of steel**

110 G13L / wt %					
C	Mn	Si	S	P	Al
1,36	11,42	0,70	0,019	0,033	0,031

Metallographic analysis of the obtained samples of the original steel in the cast state before heat treatment. Figure 1 shows the non-metallic inclusions of steel without modification, of the field of view is 71, 62 µm (3 x).

Studies experienced cast steel under a microscope shows that the metal has not passed processing modifiers, significantly contaminated with non-metallic inclusions. The nature of the non-metallic phase consists of clusters of sharp-angled aluminum oxides Al2O3 (corundum), iron-marginalistic oxides (Fe, Mn) O multiphase inclusions in the form of particles of corundum, edged with iron-manganese sulfide (Figure 2)

The steel structure is not heat-treated steel were determined after etching in 4 % solution of nitric acid in ethyl alcohol. Metallographic studies showed that the



a - alumina; b - fluid inclusions

Figure 1 Non-metallic inclusions in the steel without modifiers (field of view is 71,62 µm (3 x))

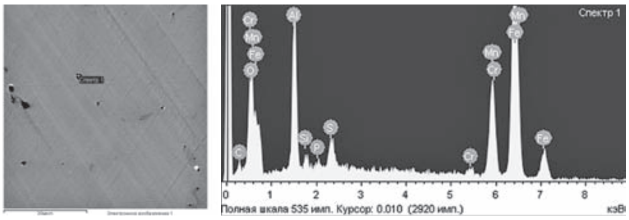


Figure 2 The chemical composition of nonmetallic inclusions steel without modifiers

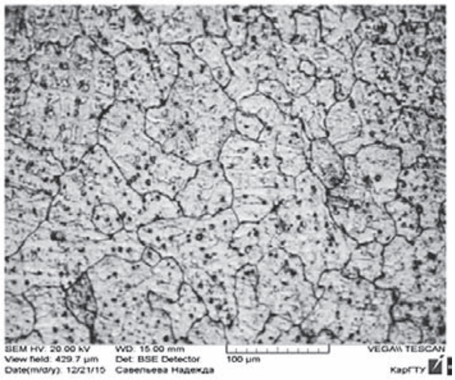


Figure 3 The microstructure of the steel after etching (field of view is 429,7 µm (500 x))

metal has a coarsely granular structure consists of austenite, the excess carbides (Fe, Mn) 3C and numerous inclusions, precipitated at the grain boundaries and inside the grain (Figure 3).

The separated inclusions at the grain boundaries, contaminate the metal and reduce inter granular strength, which leads in some cases to the formation of hot cracks and destruction of the castings during solidification in the form, during heat treatment. Metallographic analysis also targeted the microsections obtained in the modification process have become complex FASC alloy (Figure 4).

As seen in Figure 5 a modified alloy FASC experienced 110G13L grade steel non-metallic inclusions have a different morphology and is represented mainly

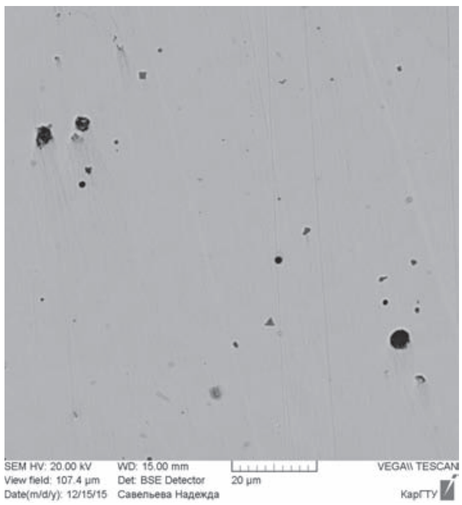


Figure 4 Globular inclusions in steel 110G13L with TASK (field of view is to 107.4 µm (2 x))

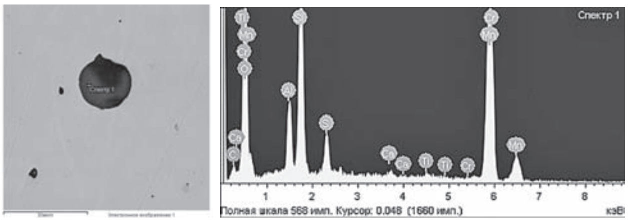


Figure 5 The chemical composition of nonmetallic inclusions steel modified FASC

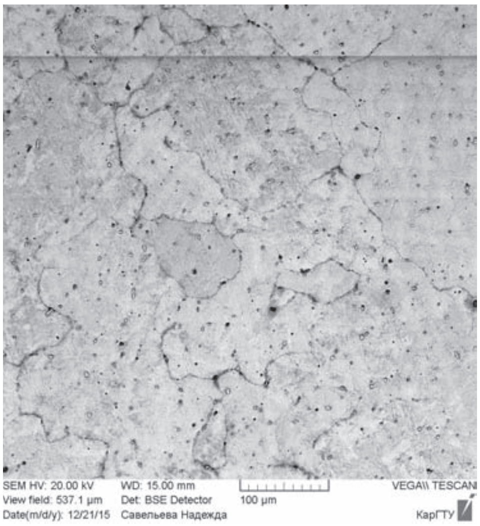


Figure 6 The microstructure of the modified steel after etching (field of view is 537,1 μm (400 x))

by globules of different sizes of silicates, complex conglomerates, globules with crystals of other minerals on the surface.

The cast structure is not heat-treated steel were determined after etching in 4 % solution of nitric acid in ethyl alcohol

Non-metallic inclusions as shown in figure 6 mostly globular in shape, small in size, are placed inside the grain. Bright field of view, they are black with a shiny dot in the center and ring light, dark field of view inclusion, therefore, possess a high degree of transparency. This indicates significant positive impact of calcium as a modifier of non-metallic inclusions and steel structure.

CONCLUSIONS

In the developed technology of smelting high-manganese steels provided the final aluminum deoxidation and modification of melt metal complex alloy (FASC). In this case the residual aluminum content in the steel must be at the optimal level, due to the fact that steel melted and due to the particular composition of 110G13L steel (high manganese content) it is prone to saturation with nitrogen. When receiving the high content of nitrogen and aluminum in steel intergranular film formed nitride AlN, which significantly reduces the operating properties, increasing its susceptibility to cracking.

According to a study proposed to substitute in the smelting of high-manganese steel, cast aluminum on the other deoxidizer-modifier that would provide a more predominant use of aluminum as the deoxidizer, and not nutritionnatural – *ferroalumisilicocalcium* (FASC). Found that, in the smelting of steel 110G13L oxygen activity a[O] in the molten steel must be not more than 7 ppm, which corresponds to deoxidizing slag Σ(FeO + MnO) not more than 6 %.It was established experimentally that the treatment of steel 110G13L complex alloy (FASC) increases the absorption of aluminum, cast grinding grain by 2 points and the modification of nonmetallic inclusions. To implement the above technical solutions to improve the quality of castings of steel 110G13L you must meet the following conditions:

- deep deoxidizing steel, which corresponds to the optimal content of residual aluminum in the metal (0,040 %);

technology use at the final stage of smelting steel modification with the replacement of the aluminum parts are more effective complex deoxidizer-modifier FASC that contributes to high purity non-metallic inclusions. Steel cut complex (0,5 % FASC + 0,16 % aluminum).

The optimal amount of modifying additives (FASC) for a complete modification of non-metallic inclusions, which 0,5 % by weight of machined metal.

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Note: The responsible translator for English language is Nataliya. Drag, Karaganda, Kazakhstan