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STUDYING POSSIBILITY OF SMELTING REFINED FERROMANGANESE GRADES USING SILICON ALUMINUM REDUCER

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Preliminary Note – Prethodno priopćenje

In the given article there are presented the results of smelting refined grades of ferromanganese using silicon aluminum reducer. There is established the possibility of smelting medium-carbon ferromanganese of the FeMn-80C20LP grade (ISO 5446-80). The extent of extraction and effective use of basic elements reaches 51,1 – 51,2 % of manganese, 54,5 - 59,8 % of silicon and 82,5 – 89,5 % of aluminum.

Key words: ferromanganese alloy, smelting, reduction, silicon, aluminum

INTRODUCTION

Global production of crude steel has increased significantly since the early part of the 20th century, from a few tens of millions mt in 1900 to approximately 1,600 million mt in 2015. It is anticipated that production of crude steel will continue to increase over the next 20 years, reaching approximately 2,500 million mt by 2030 (Figure 1) [1].

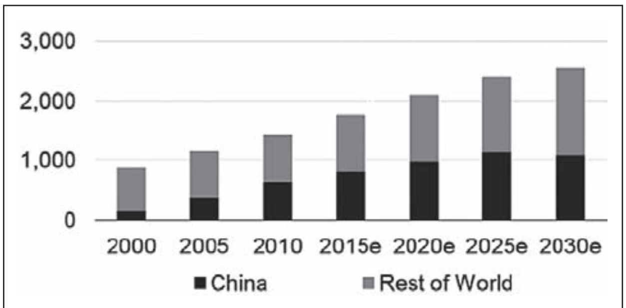

Figure 1 The volume of world steel production from 2000 to 2030 / million mt.

This steady increase in world steel production associated with the increasing demand integral iron and steel industry in various ferroalloys. One of the most commonly used is manganese ferroalloys (high- and low-carbon ferromanganese, silicon manganese, iron and manganese). Therefore, the increase in steel production is accompanied by increased production of manganese ore and smelting of manganese ferroalloys. Note that the major share in world production of manganese alloys occupy silicomanganese production with a share of 68%, medium-carbon ferromanganese 23% and refined ferromanganese 9% (Figure 2) [2,3].

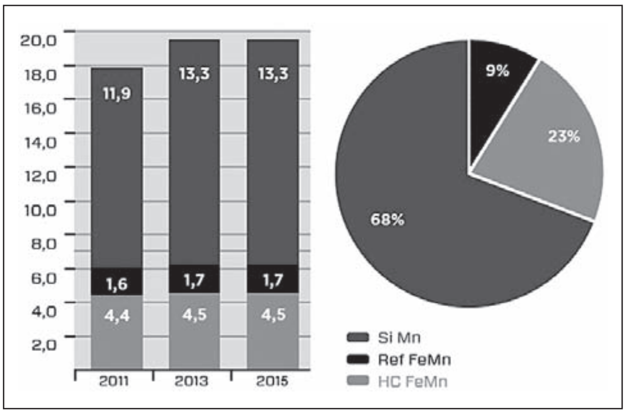

Figure 2 Global Mn alloy production / million mt.

It is known that the technology of silicothermal smelting of refined ferromanganese grades is two-stage.

At the first stage in ore-thermal furnaces there is melted ferrosilicon manganese by the carbothermal slag method from manganese ore with the manganese content not less than 38 - 40 % using metallurgical coke as a reducer. At the second stage by the silicothermal method in refining furnaces there is melted medium- or low-carbon ferromanganese from rich manganese ore with the manganese content not less than 46 - 48 % using ferrosilicon manganese as a reducer [4,5].

In the Republic of Kazakhstan there are all prerequisites, namely the raw manganese base, the scientific potential and idle electric arc furnaces of refining type, for expanding the range of the produced manganese ferroalloys by means of organizing the production of refined ferromanganese grades. At this so far in Kazakhstan the production of refined ferromanganese grades has not been developed. This is explained by the fact that in the existing technology of silicothermal smelting of refined grades of ferromanganese there is a number of shortcomings:

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- low extraction of manganese from ore (no more than 45-50 %) at the stage of silicothermal reduction;
- high requirements to manganese raw materials (to which there do not satisfy domestic manganese ores) for ferromanganese smelting;
- dispersal of final slag after cooling (sharply worsens the ecological situation);
- accumulation of significant amounts of dump manganese slags.

One of the prospective trends of improving the technology of smelting refined brands of ferromanganese is using as a reducer not silicon as it is accepted in traditional technologies, but aluminum as a stronger reducer. Aluminum use as a reducer when smelting ferromanganese is not widely spread and is limited, owing to its high cost.

STATEMENT OF THE AIM OF THE STUDY

Therefore carrying out studies for obtaining refined ferromanganese grades using cheap aluminum-bearing alloy as a reducer which in addition contains silicon and manganese in the composition is a topical task.

At the first stage of the work there was defined the task of obtaining a cheap aluminum-bearing reducer, namely a complex alloy of alumosilicon manganese. As manganese raw materials there were used the ores of the Zapadny Kamys deposit of the following chemical composition: 21,5 % Mn; 3,27 % Fe_2O_3; 40,35 % SiO_2; 6,5 % Al_2O_3; 4,81 % CaO. As a reducer there was used the Saryadyr high-ash coal with the ash content 42,26 %, volatile components 22,63 % and 36,06 % of solid carbon. The ash chemical composition was: 55,6 % SiO_2; 34,31 % Al_2O_3; 0,86 % CaO and 2,31 % Fe_2O_3.

METHODOLOGY OF SOLVING THE TASKS OF THE STUDY

The smelting alumisilicon mangenese was performed in an ore-thermal furnace with the transformer of 0,2 MVA power at various ratios of the basic materials in the burden.

As a result of the carried out tests for smelting a complex alloy, alumisilicon mangenese, there was obtained a high-quality ferroalloy with aluminum content to 16 - 20 %. The elements extraction made 84,8 % Mn; 76,5 % Si; 68,9 % Al.

The tests of ferromanganese smelting were carried out in an electric rocking furnace of refining type with the 0,1 MVA transformer. The working voltage of the transformer was 49 V. For purity of the experiment the furnace was lined with magnesite fire-resistant bricks of the MP-95 grade, with filling magnesite powder in the seams. The furnace was equipped with two graphitized electrodes which diameter makes 100 mm.

EXPERIMENTAL WORK

At the following stage there were carried out tests for smelting refined ferromanganese grades. As the burden materials there was used manganese ore of the Mynaral field and lumpy lime. Alumosilicon manganese obtained at the first stage with various chemical compositions acted as a reducer. Chemical compositions of the materials are given in Table 1.

Table 1 **Characteristic of the ore burden materials / wt. %**

Material name	Mn	Fe	SiO_2	CaO
Manganese ore of Mynaral	49,23	0,92	10,83	1,18
Lime	-	-	1	76,96
AMS -1	Mn	Si	Al	Fe
	22,95	45,32	16,71	10,38
AMS -2	36,94	44,12	5,98	8,70
AMS -3	31,51	49,23	6,31	9,51
	Al_2O_3	S	P	lol
Manganese ore of Mynaral	1,22	0,01	0,033	7,70
Lime	0,18	0,006	0,005	20,54
AMS -1	C	Ca	P	Ti
AMS -2	0,46	0,80	0,048	0,20
AMS -3	0,36	1,23	0,068	0,23

The electric furnace heating up was made within 4 hours using a coke pillow as the conductor of electric current. At the end of the heating up period the bathtub was cleared completely of the remains of the coke pillow. The electric mode of the heating up period was as follows: voltage 49 V, loading on the electrodes 100 - 120 A.

The melting process was periodic with the average duration of 1,5 – 2,0 h., i.e. the furnace burden was loaded after setting the current loading. The furnace burden was loaded in the following order. Under the current loading (the loading was gathered on the melt which had remained in the furnace, and in its absence there was loaded a part of alumosilicon manganese: 1 – 1,5 kg). There was loaded the entire mass of the burden materials. Within the smelts the current loading was kept uniform (I = 100 - 120 A), the emissions on the top were not observed. The slag was liquid, active. After the furnace burden melting, the slag and metal were let out from the lower tap-hole. After cooling the metal and slag were well divided. The slag did not scatter.

The melted metal and slag after cooling and sampling was exposed to the chemical analysis which results are presented in Table 2.

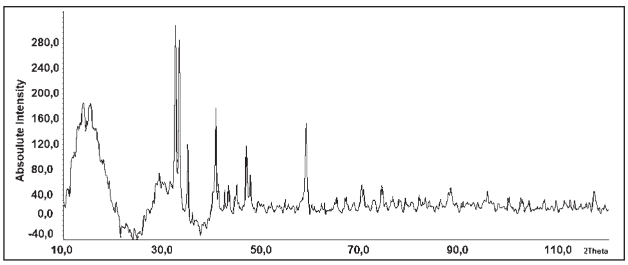

Figure 3 X-ray-gram of manganese slag

Table 2 **Slag and metal chemical composition / wt. %**

No	Metal						
	Mn	Al	Fe	Si	C	P	-
1	76,5	1,8	10,5	12,4	0,51	0,050	-
2	71,7	1,9	10,2	18,7	0,31	0,056	-
3	74,2	1,6	8,6	14,2	0,23	0,052	-
4	76,3	1,5	8,9	12,4	0,63	0,058	-
5	-	-	-	-	-	-	-
6	77,2	1,9	9,9	11,5	0,5	0,058	-
7	71,5	1,8	9,0	18,3	0,18	0,052	-
8	71,3	1,7	9,9	16,4	0,39	0,063	-
No	Slag						
	MnO	Al_2O_3	$Fe_{общ}$	SiO_2	CaO	P_2O_5	MgO
1	24,3	9,7	0,57	23,0	35,7	0,029	0,68
2	20,3	10,5	0,47	23,4	39,2	0,025	0,56
3	26,1	6,7	0,78	25,5	38,5	0,029	0,68
4	28,3	8,4	0,88	25,1	36,4	0,023	0,55
5	25,4	9,4	0,41	25,9	39,9	0,023	1,36
6	27,2	10,0	0,41	25,3	39,2	0,019	0,65
7	-	-	-	-	-	-	-
8	27,6	8,7	0,36	26,4	40,0	0,017	1,25

By the X-ray phase analysis on the Dron 4 diffractometer (Figure 3) it was established that the final slag of the refined ferromanganese consists of two-calcic silicate (Ca_2SiO_4) and manganosite (MnO) (Table 3).

Table 3 **Data of the X-ray-structural phase analysis**

Sample		[20-237] – Ca_2SiO_4		[75-626] – Ca_2SiO_4	
D	Int	D	Int	D	Int
6,391	21				
2,75	100	2,747	100		
2,687	95	2,69	75		
2,561	42			2,56026	640
2,218	65	2,186	50	2,21725	999
2,018	15	2,022	30		
1,937	36	1,937	30		
1,91	18	1,905	30		
1,568	50	1,584	30	1,56783	468
1,34	15			1,33705	163

CONCLUSION

As a result of the carried-out tests for smelting refined ferromanganese grades it is possible to draw the following conclusions:

- large laboratory studies proved the possibility of smelting medium-carbon ferromanganese of the FeMn-80C20LP grade (ISO 5446-80) with the use of a complex reducer of alumosilicon manganese;
- the key electric parameters of the technology: working voltage is 49 Volts and current is 100 - 120 Amperes;
- the extent of extraction and effective use of basic elements reaches 51,1 – 51,2 % of manganese, 54,5 - 59,8 % of silicon and 82,5 -89,5 % of aluminum;
- the obtained alloy is characterized by the raised content of silicon. It is necessary to make the melt purge with compressed air for obtaining standard for silicon content alloy or to add an oxidizing mix made of ore and lime. At this the obtained alloy has a low carbon content (0,3 - 0,5 % C instead of 2 %) and phosphorus (0,017 – 0,029 % P instead of 0,1%);
- owing to the fact that the manganese content in ferromanganese depends on its content in the reducer, for the purpose of obtaining a metal corresponding to the FeMn90C20LP grade (ISO 5446-80) it is needed to use alumosilicon manganese with the manganese content not less than 40 - 45 %. Therefore, when smelting alumosilicon manganese it is necessary to use high-ash coals with the ash-content less than 42 % and to increase the share of manganese ore in the burden.

Thus, as a result of studies there was established the basic possibility of smelting refined ferromanganese grades using alumosilicon manganese a reducer in large-laboratory conditions in the electric furnace of refining type with the transformer power 0.1 MVA.

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Note: The responsible translator for English language is N. Drak, Karaganda, Kazakhstan