A. ABDIRASHIT, YE. MAKHAMBETOV, A. YERZHANOV,
ZH. SARKULOVA, N. AITKENOV, N. AITBAYEV

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LARGE-SCALE LABORATORY TESTS FOR SMELTING MEDIUM-CARBON FERROMANGANESE USING JEZDA MANGANESE ORE AND SiMn17 SILICOMANGANESE FINES

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Preliminary Note – Prethodno priopćenje

At present, Kazakhstan has established production of ferrosilicomanganese, while refined ferromanganese is not produced. This is primarily due to a lack of high quality feedstock, as well as a lack of theoretical and applied research into new production conditions. To address these issues we conducted large-scale laboratory tests on smelting medium-carbon ferromanganese by one-stage silicothermic method. As a result of these tests, medium-carbon ferromanganese meeting the standard grade with more than 80 % manganese content was produced.

Key words: medium-carbon ferromanganese, manganese ore, SiMn17, manganese slag, refining furnace.

INTRODUCTION

Refined ferromanganese is produced mainly by silicothermic reduction of manganese contained in manganese ore or slag in steel arc furnaces or in ladles [1-3]. The first method is used at the plant of Prometal (Cumbic, Brazil), the second - at the plant of Transalloys (South Africa), two plants of Sofrem in Saint-Beron and Marigner-LeGiffre (France), as well as at the plants of Taihayokinzoku and Mizushimaferroeloyz (Japan), etc. Production capacity of medium-carbon ferromanganese plant in Saint-Beron is 30 000 tonnes per year.

The reserves of manganese ores in the country by their absolute value are sufficient to supply the metallurgical enterprises of the Republic of Kazakhstan, but the obstacle to the use of ores has been their unsatisfactory quality [4-7]. Along with the requirements for ore quality in terms of phosphorus and silica content, there is also a limitation in terms of iron content. This point is missing in the universal complex technology for processing of manganese ore, which could provide the operating enterprises of the country with high quality raw materials. Currently Kazakhstan produces only ferrosilicomanganese, while there is no production of refined ferromanganese at all. This is primarily due to a lack of quality feedstock materials, as well as a lack of theoretical and applied research adapted to new production conditions.

A. Abdirshit (e-mail: asik_942017@mail.ru), Ye. A. Yerzhanov (e-mail: a.yerzhanov@ttt.edu.kz), N. Aitkenov, Karaganda Industrial University, Temirtau, Kazakhstan
Ye. Makhambetov, Chemical and metallurgical institute named after J.Abishev, Karaganda, Kazakhstan
Z. Sarkulova, Aktobe regional of university named after K. Zhubanova, Aktobe, Kazakhstan
N. Aitbayev, Abylksa Saginov Karaganda Technical University, Karaganda, Kazakhstan

In Kazakhstan, ferrosilicon manganese and refined ferromanganese are mainly imported from JSC Chelyabinsk Electrometallurgical Plant (Russia), Zaporozhye Ferroalloy Plant (Ukraine), as well as from China. In 2022, due to currency fluctuations and geopolitical situations in the region, supplies will become much more difficult. Therefore, research and development of a resource-saving technology for smelting manganese ferroalloys, marketable medium-carbon ferromanganese, is an urgent task. Moreover, the organization of such production on an industrial scale will create new jobs, both at metallurgical plants and at mining enterprises for processing of manganese ore and concentration wastes. The commercial medium- carbon ferromanganese obtained as a result of the study is import-substitutable [11,12].

RESEARCH METHODOLOGY

Studies on the smelting of medium-carbon ferromanganese using Jezda manganese ores and silicomanganese fines were carried out on a 100 kV·A transformer refining furnace in a single-stage silicothermic process. The operating voltage of the transformer was 49 V. The furnace was lined with magnesite refractory bricks, grade MP-95, with seams filled with magnesite powder. The furnace was equipped with two graphite electrodes with a diameter of 100 mm. Experiments were carried out in the conditions of the Chemical and Metallurgical Institute named after J.Abishev Chemical composition of initial charge materials are given in Table 1.

Smelting was carried out continuously, with periodic loading of charge (mass of one ear of charge mixture loaded into the furnace was 100 kg), every two hours steel rod carried out the release of metal in the

Table 1 **Chemical composition of charge materials / wt. %**

Name material	Content / %								
	Mn_{tot}	Fe_2O_3	SiO_2	Al_2O_3	SaO	MgO	P_2O_5	S	PPP
Manganese ore	48,23	3,45	12,48	2,76	1,28	1,47	0,03	0,01	7,7
Lime lumps	-	0,62	1	0,18	80,96	1,14	0,005	0,006	20,54
Metal part	Mn		Fe		Si		Al	Ca	C
Silicomanganese	60 - 65		7 - 10		16 - 18		0,44	0,71	1,13

Table 2 **Chemical composition of slag and metal / wt. %**

№ of the issue	Chemical analysis of metal / %						Chemical analysis of slag / %				CaO /SiO_2
	Mn	Al	Si	C	P	Fe	MnO	Al_2O_3	SiO_2	CaO	
1	81,43	0,078	1,68	1,56	0,33	other	27,15	2,28	29,28	34,19	1,16
2	80,99	0,079	2,59	1,84	0,27	other	23,41	2,23	28,09	35,88	1,27
3	81,99	0,11	2,62	1,11	0,3	other	23,15	2,28	29,28	35,14	1,20
4	81,45	0,019	2,54	1,63	0,33	other	25,98	2,18	25,62	34,81	1,36
5	82,57	0,13	2,28	1,45	0,26	other	25,41	3,41	25,17	33,54	1,33
6	82,26	0,14	1,26	1,44	0,24	other	28,62	2,76	27,41	30,79	1,12
7	80,34	0,084	4,72	1,61	0,28	other	19,69	3,66	28,16	29,74	1,06

cast iron pots, the metal came out of the furnace actively, for one release weight of metal was from 30 to 45 kg. The duration of melting is 100 - 120 minutes. The current load is 100 - 120 A. Metal andslag came out hot, the slag was active. The overall performance of the furnace was characterized by the stability of the melting process, as evidenced by the stablecurrent load and the timely active release of metal. After each release, the metal and slag were weighed and samples were taken for chemical analysis (Table 2).

RESULTS RESEARCH

The pilot batch of medium-carbon ferromanganese obtained under coarse -laboratory test conditions corresponds to FeMn80C15, with an average manganese content of 80 %, manganese recovery 40 - 60 %.

Table 3 **The degree of extraction of the main elements in the smelting of refined ferromanganese / wt. %**

Products	Mn_{total}	Mn_{ore}	Fe	Si	Al	Ca
metal	61,0	35,2	91,0	20,7	5,5	-
slag	34,5	57,3	8,6	71,7	91,9	79,8
fly away	4,5	7,5	0,4	7,6	2,6	20,2

It should be noted that due to the lack of express analysis of the metal and slag, there was a delay in the regulation of the charge, the process and the course of melting, as a result, the calculated value of the optimal basicity of 1,3 - 1,4 was not achieved. Perhaps this is due to a slightly overestimated real silicon content in the reducing agent and in the charge as a whole and, consequently, an underestimated content of calcium oxide in the final slag. This mainly explains the underestimated extraction of manganese from the ore in comparison with the calculated and planned one (Table 3). Nevertheless, the resulting metal meets the requirements of GOST and ISO, and the technological process is characterized by stability and predictability.

The obtained data give grounds to draw a conclusion about the economic and technological feasibility of organizing the production of medium-carbon ferromanganese using the developed technology on a mini-production scale to provide the domestic market with a subsequent prospect of entering the world market.

The X-ray phase studies of the mineralogical composition of the obtained experimental manganese slags at the DRON-2 installation revealed that the phase composition of the experimental slags includes dicalcium

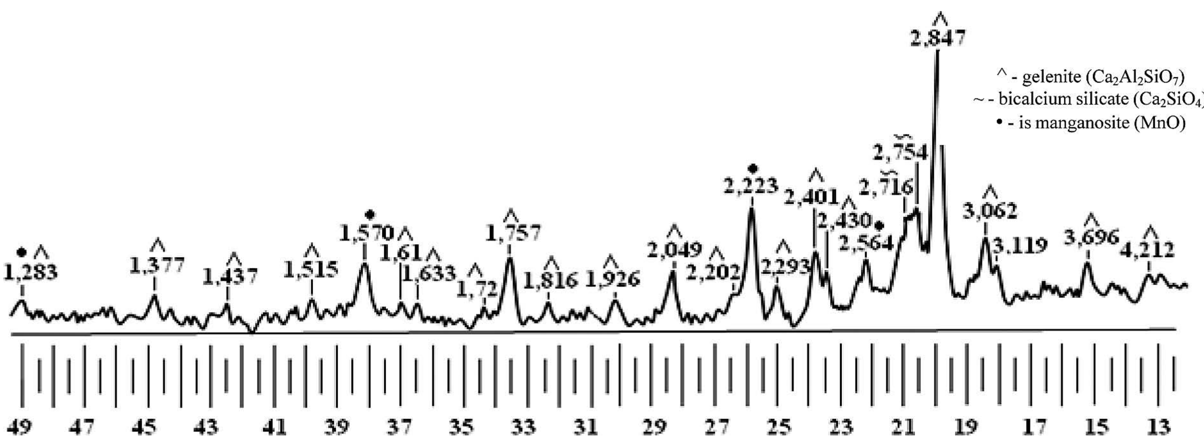

Figure 1 X-ray of manganese slag

silicate (dicalcium silicate is a solid solution of the general formula $(Ca_{1-x}Mnx)_2SiO_4$) and manganosite (MnO). Manganosite in the form of individual grains is located both along the boundaries of continuous regions of dicalcium silicate and within these regions. This suggests that MnO precipitates into a separate phase simultaneously with Ca_2SiO_4 crystals from the liquid phase. An X-ray ofthe phase composition of the slag is shown in Figure 1.

CONCLUSION

As a result of the medium-carbon ferromanganese smelting tests carried out, the following conclusions can be drawn:

- The pilot batch of medium-carbon ferromanganese obtained under coarse- laboratory test conditions corresponds to FeMn80C15, manganese content 80 %.
- the basic electrical parameters of the technology 110-130 Ampere current;
- manganese slag is in the form of bicalcium silicate (Ca_2SiO_4); helenite (Ca_2Al_2 SiO_7) and manganosite (MnO);

Thus, under large-scale laboratory conditions, tests were carried out for the metallurgical evaluation of dzhezdy manganese ores and silicomanganese fines on a 100 kVA transformer-type electric refining furnace and a pilot batch of more than 3 tonnes was produced.

REFERENCES

[1] Gasik M.I. Elektrotermiya marganca. Kiev, Tekhnika, 1979. (Russian)

[2] Gasik M. I. Marganec. – M.: Metallurgiya, 1992. - 608 s. (Russian)

[3] O.R. Sariev, M.S. Dossenkenov, B.S. Kelamanov, A. M. Abdirashit. High-carbon ferromanganese smelting on high-base slags. Kompleksnoe ispolzovanie mineralnogo syra (2020) 4, 63-73. (DOI:10.31643/2020/6445.38).

[4] E. K. Mukhambetgaliev, A. B. Esenzhulov, V. E. Roshchin. Alloy Production from High-Silica Manganese Ore and High-Ash Kazakhstan Coal. Steel in Translation, 48 (2018) 9,547-552.(https://doi.org/10.3103/S0967091218090097).

[5] V. I. Zhuchkov, A. V. Zhdanov, O. V. Zayakin. Research of softening temperatures of manganese raw materials The Melts (2006) 3, 29-32.

[6] E. A. Buketov, T. G. Gabdullin, T. D. Takenov. Metallurgical processing of manganese ores in Central Kazakhstan. Nauka, Almaty, 1979, p.184

[7] Kolesnikov A.S., Sergeeva I. V. et al. Thermodynamic simulation of chemical and phase transformations in the system of oxidized manganese ore - carbon. Izvestiya Ferrous Metallurgy 60 (2017) 9, 759 -765. (https://doi.org/10.17073/0368-0797-2017-9-759-765).

[8] Ye. Makhambetov, A.Abdirashit, Ye. Kuatbay, A. Yerzhanov, G. Issengaliyeva, A. Angsapov. Research of microstructure and phase composition of a new complex alloy - alumosilicomanganese (Al-Si-Mn). Metalurgija 61 (2022) 3-4, 804-806.

[9] Ye. Kuatbay, A. Nurumgaliyev, Ye. Shabanov, O. Zayakin, S. Gabdullin, T. Zhuniskaliyev. Melting of high-carbon ferrochrome using coal of the Saryadyr deposit. Metalurgija 61 (2022) 2, 367-370.

[10] Mukono, T., Wallin, M., Tangstad, M. Phase Distribution During Slag Formation in Mn Ferroalloy Production. Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science 53 (2022) 2, 1122-1135.

[11] Mukono, T., Wallin, M., Tangstad, M. Slag Reduction and Viscosities Interaction in Ferromanganese Process. Minerals, Metals and Materials Series (2022), 145-158.

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