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Metallurgical Evaluation of Zhaksylyk Manganese Ore Concentrate for Ferrosilicomanganese Smelting

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Abstract. *The purpose of this work is the metallurgical evaluation of the manganese ore of the Zhaksylyk deposit for the smelting of ferrosilicomanganese. For this, the phase composition of the concentrate was studied by X-ray phase analysis on an Empyrean Malvern Panalytical X-ray diffractometer, where brownite ($MnO{\cdot}3Mn_2O_3{\cdot}SiO_2$) and quartzite ($\alpha$-$SiO_2$) phases were detected. A certain granulometric composition of the concentrate of sequential sieve analysis, by size 25-10, 10-8, 8-5, 5-3 and 3-0 mm, followed by weighing the size of the classes and calculating their income as a percentage of the total mass of the sample. According to the chemical analysis, the average composition of the manganese concentrate is given, %: Mn_{total} – 36,93; Fe_{total} – 6,21; MgO – 0,72; SiO_2 – 38,33; CaO – 26,17; Al_2O_3 – 4,05; P_{total} – 0,042. In Tamman's high-temperature laboratory furnace, a series of crucible melting of ferrosilicomanganese was carried out using manganese concentrate from the Zhaksylyk deposit; the resulting ferrosilicomanganese corresponds to GOST 4756-91 in terms of chemical composition.*

Keywords: *manganese concentrate, ferroalloy, ferrosilicomanganese, carbothermy, phase composition, granulometric composition, ore.*

Introduction. The reserves of manganese ores in the Republic of Kazakhstan are sufficient in absolute terms to meet the needs of the country's ferroalloy plants, but an obstacle to their use on an industrial scale is the unsatisfactory quality of the ores of most deposits [1-3]. The main reserves of ores (about 70%) are represented by ferromanganese varieties. The remaining 30% are refractory oxidized and primary manganese ores. In works [4-6], the growing problem of the lack of high-quality manganese ores was noted, which is still relevant. This moment of production is facing an excessive delay by the introduction of new technologies for the processing of manganese ores, it is necessary to quickly explore and give a metallurgical assessment of new ore deposits that could provide the operating capacity of ferroalloy plants, for example, the Karaganda plant of «Asia FerroAlloys» LLP and the Aksu ferroalloy plant of TNC «Kazchrome». One of the promising deposits of manganese ores in Kazakhstan is Zhaksylyk, therefore, as part of this work, a metallurgical assessment of the manganese concentrate of this deposit was carried out. To date, Kazakhstan ferroalloy plants do not use this manganese concentrate on an industrial scale as a feedstock, so the results of the study are of practical and scientific significance. Data on the granulometric, phase composition of the ore and the results of a study of reduction processes with various carbonaceous reducing agents, the softening temperature of the ore can replenish the database for the development of a technology for smelting ferrosilicomanganese.

Research methods. To assess the qualitative and quantitative characteristics of the studied manganese concentrate, a number of physical and chemical studies were carried out to establish its metallurgical suitability. First of all, there is a question about the content of the main components in the material.

To identify the phase composition of alloy samples, the method of X-ray phase analysis was used. The phase composition of the materials was studied by X-ray phase analysis on an Empyrean Malvern Panalytical X-ray diffractometer.

The sieve analysis method was used to determine the granulometric composition of the concentrate and the distribution of valuable components by size classes +40, 40-25, 25-10, 10-8, 8-5, 5-3 and 3-0 mm. Laboratory studies on the smelting of ferrosilicomanganese from the concentrate of manganese ores from the Zhaksylyk deposit were carried out in a Tamman high-temperature electric furnace. The Tamman High Temperature Furnace is a high temperature research facility used to simulate metallurgical processes. During smelting, for the normal mode of reduction processes to occur, it is desirable to have a uniform melting (softening) temperature of the ore and the reducing agent. The softening temperature affects the descent of charge materials into the reaction zone, which can be a determining factor in the whole process itself [7]. Therefore, in laboratory conditions, in addition to weight loss, the softening temperature of the ore and charge mixture was measured when heated.

Research results. At the initial stage, the ore was quartered to take an average sample for chemical analysis. The results of the chemical and technical analysis of the initial charge materials for the smelting of ferrosilicomanganese are shown in tables 1 and 2.

As a result of X-ray phase analysis, brownite ($MnO \cdot 3Mn_2O_3 \cdot SiO_2$) and quartz ($\alpha$-$SiO_2$) phases were revealed.

The granulometric composition was determined by sieve analysis, which is based on determining the quantitative distribution of pieces by size by dry sieving on several sieves, followed by weighing the obtained size classes and calculating their yield as a percentage of the total mass of the sample taken for sieving. The sieving of the sample was carried out manually using the following set of sieves: 25-10, 10-8, 8-5, 5-3 and 3-0 mm. The results of determining the particle size distribution are shown in table 3.

Table 1 – Characteristics of ore charge materials

Material name	Chemical composition, %								
	Mn_{total}	Fe_{total}	MgO	SiO_2	CaO	Al_2O_3	S	P_{total}	P.P.P.
Manganese concentrate	36,93	6,21	0,72	38,33	26,17	4,05	1,29	0,042	6,15
Limestone	-	-	-	0,51	54,32	0,14	0,016	0,012	4,1
Quartzite	-	-	-	98,48	1,19	0,37	0,01	0,0034	-

Table 2 – Technical composition of the carbonaceous reducing agent

Material	V^p	W^p	A^p	$C_{solid.}$	S
Coke	1.14	0.21	13.35	85.29	0.88
Coal	10,51	2,06	37,54	35,60	0,04

Table 3 – The content of valuable components by size class

Fraction size	Composition, %									
	Mn_{total}	Fe_{total}	MgO	MnO_2	MnO	SiO_2	CaO	Al_2O_3	P_{total}	Mass, g	Output, %
3-0	34,38	5,89	0,72	33,73	41,42	27,59	1,94	3,93	0,035	3,35	3,35
5-3	36,93	6,00	0,72	40,33	40,63	26,17	1,94	4,05	0,042	10,32	10,32
8-5	35,63	5,37	0,72	33,33	43,37	26,71	1,94	3,85	0,048	22,25	22,25
10-8	34,35	5,78	0,36	37,80	42,10	26,63	1,94	4,02	0,043	61,53	61,53
25-10	40,81	4,11	0,36	39,84	40,58	22,44	1,94	2,81	0,044	2,55	2,55

In the course of laboratory studies, a series of crucible melts with different ratios of charge materials was carried out. The charge consisted of manganese concentrate using metallurgical coke and high-ash coal of the Borly deposit as reductants. Quartzite and limestone were used as the fluxing material.

The dosed and mixed charge mixture was poured into a graphite crucible and placed in a furnace. Exposure was carried out from 40 to 80 min at temperatures of 1650-1675°C. The results of chemical analysis are shown in table 4.

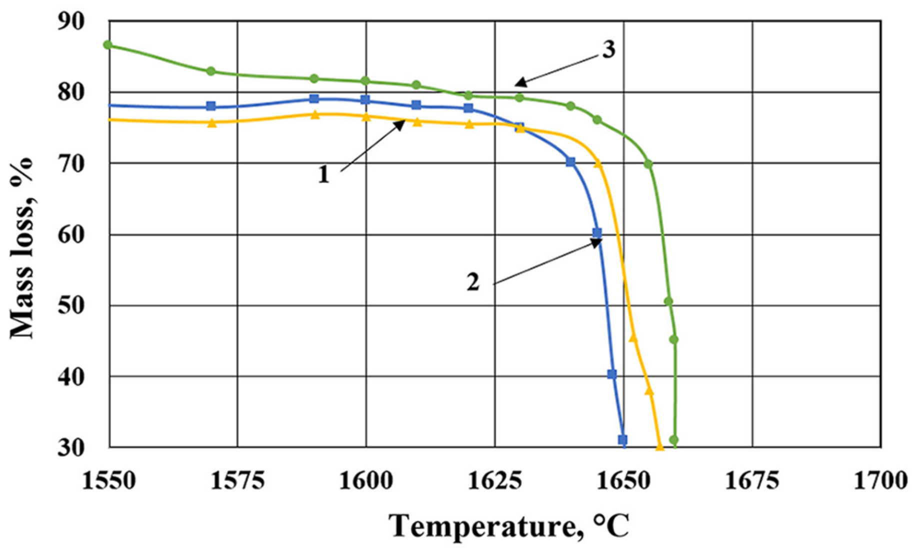
During the crucible heats, the mass loss of the charge mixture was continuously recorded. Sharp inflections in Figure 1 at temperatures of 1640-1660°C indicate the beginning of reduction processes, there are losses of gas into carbon monoxide and volatile substances.

The kinetic data are in good agreement with the data on the measurement of the softening temperature of the concentrate and charge mixture. The softening temperature of the ore mainly depends on the constituent of the oxide part.

In the process of softening when heated, new mineral compounds and eutectics are continuously formed in the ore, internal

Table 4 – Chemical composition of melt products

Charge mixture	Cast №	Slag, %				Metal, %			
		MnO	SiO_2	Al_2O_3	CaO	Mn	Fe	Si	C
Manganese concentrate, quartzite, limestone, coke	1	11,44	50,1	14,32	23,44	59,12	10,48	12,41	2,24
	2	7,58	48,7	10,94	26,88	65,87	9,18	16,56	1,25
	3	8,24	51,2	11,64	22,56	66,48	11,25	17,61	1,74
	4	7,22	48,1	9,62	30,08	63,78	11,47	18,85	1,88
Manganese concentrate, quartzite, coke, coal	5	6,62	51,6	8,28	32,14	65,46	10,25	17,46	1,54
	6	8,79	52,2	6,94	22,45	66,72	9,58	15,10	1,46
	7	9,42	48,7	8,77	28,26	62,98	12,83	16,74	1,88
	8	8,46	51,3	4,26	26,32	66,24	11,32	13,38	1,69



1 – Charge mixture: manganese concentrate, quartzite, limestone, with coke (consumption of solid carbon by stoichiometry); 2 – Charge mixture: manganese concentrate, quartzite, limestone, with coke (solid carbon 10%); 3 – Charge mixture: manganese concentrate, quartzite, limestone, coal
Figure 1 – Graph of change in the weight of the charge mixture during the melting of ferrosilicomanganese

cohesion forces are violated, and the ore passes into a liquid state (drop formation). Prepared samples of manganese concentrate and charge mixture (fraction 3-5 mm) were loaded into a graphite crucible. The sample was then placed in a Tamman oven. Material height 40 mm, heating rate 10°C/min. The results of the data on the change in shrinkage as a function of temperature are shown above, Figure 2.

According to the softening temperature of slag formation during the smelting of ferrosilicomanganese using manganese concentrate from the Zhaksylyk deposit, it is in the temperature range of 1550-1600°C, which has a positive effect on the smelting process in an ore-thermal furnace under industrial conditions.

Conclusion. Thus, a metallurgical evaluation of the manganese concentrate of the Zhaksylyk deposit was carried out. The phase composition of the manganese concentrate is presented in the form of brownite ($MnO\ 3Mn_2O_3\ SiO_2$) and quartz (α-SiO_2). According to chemical analysis, the average composition of manganese concentrate is as follows, %: Mn_{total} – 36,93; Fe_{total} – 6,21; MgO – 0,72; SiO_2 – 38,33; CaO – 26,17; Al_2O_3 – 4,05; P_{total} – 0,042. The suitability of manganese concentrates for smelting standard grades of ferrosilicomanganese has been established. The temperature range of reduction and slag formation is within 1600-1650°C.

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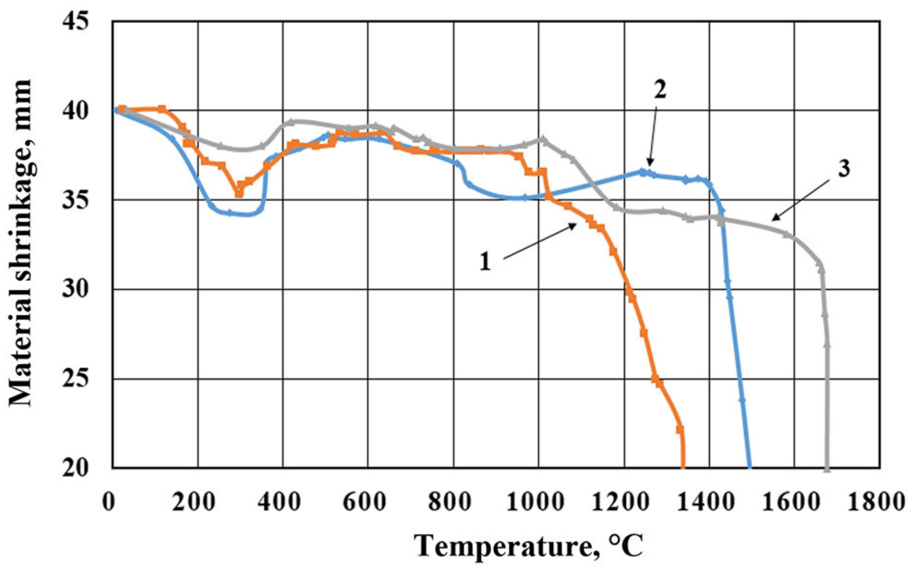

1 – Manganese concentrate Zhaksylyk, 2 – Charge mixture with coke, 3 – Charge mixture with coal

Figure 2 – X-ray pattern of Zhaksylyk manganese concentrate

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Ферросиликомарганецті балқыту үшін Жақсылық марганец кені концентратын металлургиялық бағалау

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Аңдатпа. *Жұмыстың мақсаты – ферросиликомарганецті балқыту үшін Жақсылық кен орнының марганец кенін металлургиялық бағалау. Ол үшін концентраттың фазалық құрамы броунит ($MnO·3Mn_2O_3·SiO_2$) және кварц (α-SiO_2) фазалары анықталған Empyrean Malvern Panalytical рентген дифрактометрінде рентгендік фазалық талдау арқылы зерттелді. Концентраттың гранулометриялық құрамы 25-10, 10-8, 8-5, 5-3 және 3-0 мм өлшемдері бойынша електен талдау арқылы анықталды, содан кейін алынған өлшем кластарын өлшеп, олардың шығуын үлгінің жалпы массасына пайызбен есептейді. Химиялық талдауға сәйкес марганец концентратының орташа құрамы келесідей, %: $Mn_ж$ – 36,93; $Fe_ж$ – 6,21; MgO – 0,72; SiO_2 – 38,33; CaO – 26,17; Al_2O_3 – 4,05; $P_ж$ – 0,042. Тамман жоғары температуралы зертханалық пешінде Жақсылық кен орнындағы марганец концентратын қолдану арқылы ферросиликомарганецті тигельмен балқыту сериясы жүргізілді, алынған ферросиликомарганец химиялық құрамы бойынша МЕМСТ 4756-91 сәйкес келеді.*

Кілт сөздер: *марганец концентраты, ферроқорытпа, ферросиликомарганец, карботермия, фазалық құрам, гранулометриялық құрам, кен.*

Металлургическая оценка концентрата марганцевой руды Жаксылык для выплавки ферросиликомарганца

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Аннотация. *Целью настоящей работы является металлургическая оценка марганцевой руды месторождения Жаксылык для выплавки ферросиликомарганца. Для этого был изучен фазовый состав концентрата посредством рентгенофазового анализа на рентгеновском дифрактометре Empyrean Malvern Panalytical, где были выявлены фазы браунита ($MnO·3Mn_2O_3·SiO_2$) и кварца (α-SiO_2). Определен гранулометрический состав концентрата путем ситового анализа, по крупностям 25-10, 10-8, 8-5, 5-3 и 3-0 мм, с последующим взвешиванием полученных классов крупности и вычислением их выхода в процентах от общей массы пробы. Согласно химическому анализу, средний состав марганцевого концентрата следующий, %: $Mn_{общ}$ – 36,93; $Fe_{общ}$ – 6,21; MgO – 0,72; SiO_2 – 38,33; CaO – 26,17; Al_2O_3 – 4,05; $P_{общ}$ – 0,042. В высокотемпературной лабораторной печи Таммана была проведена серия тигельных плавок ферросиликомарганца с использованием марганцевого концентрата месторождения Жаксылык, полученный ферросиликомарганец по химическому составу соответствует ГОСТ 4756-91.*

Ключевые слова: *марганцевый концентрат, ферросплав, ферросиликомарганец, карботермия, фазовый состав, гранулометрический состав, руда.*

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