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RESEARCH POSSIBILITY OF INVOLVEMENT KAZAKHSTANI NICKEL ORE IN THE METALLURGICAL TREATMENT

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The work results of laboratory tests on the involvement of Kazakhstan oxidized (silicate) nickel ores with a 0,5 – 1 % nickel content into metallurgical proccessing to obtain nickel-containing cast iron with a 3 – 5 % nickel content. The tests include the study of nickel ores by nonisothermal kinetics, the study of the structure of the phase structure of nickel ores by petrography, the process of agglomeration of nickel ores and smelting of nickel-containing cast iron from the obtaining sinter using 2 types of reducing agents (coke and coal).

Keywords: oxidized nickel ore, thermograms, coke, coal, sinter, cast iron with nickel.

INTRODUCTION

Nickel is one of the metals which widely used in various area such as: mechanical engineering, radio engineering and for alloying steel [1 - 3]. The organization of nickel production from local mineral raw materials is considered to be an urgent problem. Kazakhstan has a significant reserves of nickel ores. The largest deposits of nickel ores are concentrated in “Batamsha”, “Nikeltau”, “Rozhdestvenskoye”, “Kokpektinsk” (Aktobe region) with proven balance reserves of 423,5 million tons. The chemical and fractional composition of the nickel ore of the Batamshinsky deposit [4, 5] is presented in Table 1.

A huge reserves of nickel ores remain unclaimed in Kazakhstan due to the lack of capacities and rational technologies for their primary processing in the republic. The total reserves of nickel ores can be estimated at 580 million tons, including 423,5 million tons of proven reserves. In all deposits, the nickel content fluctuates around 1 %.

Silicate or oxidised nickel ores are not high-grade ores. They contain an insignificant amount of valuable components, including nickel (from 0,5 to 1,5 %). The main mass of these ores is waste rock. According to the content of valuable components, they are divided into nickel and iron-nickel ores. Copper, sulfur and platinum group metals are practically absent in them, but cobalt is always present, and in iron-nickel ores of the laterite type, along with cobalt, chromium is found in small quantities. The main ore minerals of oxidized nickel ores are hydrosilicates, nickel aluminosilicates (garnierite, revdinskite, etc.). Magnesian-nickel hydrosilicates and hydroaluminosilicates, or hydrated and other nickel compounds can be found sometimes in these ores, are in a finely dispersed state. There are very few large-size nickel minerals in them. Generally, waste rock consists of clay, quartz and talc.

RESEARCH METHODOLOGY

Silicate ores are characterized by a high moisture content, on average 20 - 25 %, and sometimes 30 and even 40 %. On the thermogram of nickel ores that dried in natural conditions, but only the endothermic effects of moisture removal are practically recorded (Figure 1, a) and b). Where is: DTA - differential thermal analysis; TG - thermogravimetry, DTG - differential thermogravimetry. Removal of hydrated (structural) moisture ends at 300 - 310 °C. The total loss of moisture (hydrated and hygroscope-ic) was 110 mg (9,56 %) and 143,5 mg (11,95 %). The total losses were 160 mg (13,91 %) and 200 mg (16,6 %) respectively.

Oxidized ores are highly heterogeneous and, in some cases, variable in chemical composition. Numerous experiments on the beneficiation of silicate ores have not yielded positive results so far. The impossibility of their enrichment is explained by the physicochemical nature of the mineral components in silicate ores and the nature of the distribution of nickel in them. Nickel in silicate ores is not in the form of individualized and isolated minerals, but in the form of finely dispersed hydrosilicate and other minerals in the entire mass of primary decomposition products of ultrabasic rocks. These minerals are often found at the site of contacts of serpentinites with limestones and are accompanied by very small clay rocks and hydrated iron oxides.

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Table 1 **Chemical and fractional composition of "Batamshinsk" ore / wt. %**

Materials	Samples	Fraction	Ni	Fe	Co	Cr	SiO_2	MgO	Al_2O_3	CaO
Nickel ore	№1	-5 mm	0,90	16,39	0,073	2,55	45,74	3,70	2,32	2,49
		+5 mm	0,87	14,78	0,062	1,72	49,62	3,82	2,25	1,28
		+10 mm	0,51	8,92	0,032	3,00	69,00	2,74	1,35	1,00
Nickel ore	№2	- 5 mm	1,12	16,98	0,044	2,30	48,19	4,29	1,54	-
		+5 mm	1,09	14,13	0,055	1,35	51,40	4,65	1,48	-
		+10 mm	1,23	14,38	0,039	1,69	51,57	3,52	1,87	-

Therefore, the mass of oxidized nickel ores is a soft earthy material resembling clay [6].

For a deeper study of the phase structure of domestic nickel raw materials, petrographic studies of thin sections of nickel ore from the "Batamshinskoye" deposit were carried out on an NU-2 electron microscope. Petrographic analysis data are presented in Figure 2.

It has been established that in the ores of the "Batamshinskoye" deposit, the overwhelming majority of iron is concentrated in the hematite phase. The analysis of the chemical and mineralogical composition of Kazakhstani ores showed the impossibility of metallurgical processing of these ores using existing methods, primarily due to their low quality.

RESULTS RESEARCH

One of the possible ways of involving poor metallurgical raw materials in ferroalloy processing is its preparation by several methods of agglomeration [7 - 9]. When preparing nickel ores for metallurgical processing, a large amount of ore fines is formed. Direct loading of ore fines into metallurgical units, without preliminary agglomeration, leads to a deterioration of the technological regimes of the furnace (removal of ore fines by exhaust gases during loading, the formation of a large amount of dust, sintering of the furnace top, the formation of surface blowhole, etc.), as well as to a deterioration in the general technical and economic indicators. Complete processing of fine dusty batch is possible only if it is preliminary agglomerated.

In order to determine the possibility of agglomeration of nickel ore with a size of 0 - 3 mm, studies have been investigated on agglomeration in a laboratory installation with a sinter pot 450 mm high and 250 mm in diameter. To study the process of sintering used local nickel ore ("Batamsha" deposits) with a chemical composition, % Ni – 1,12; Fe – 16,98; Cr – 2,30; SiO_2 - 48,19; MgO – 4,29; Al_2O_3 – 1,54, mixed with semi-coke (solid Carbon – 87,24 ($C_{sol.}$); Volatiles – 8,76 (V_{daf}); Ash– 2,11 (A_c); Moisture – 2,32 (Wp)). (Table 1)

The experiments were carried out according to standard technology, the layer height averaged 24 cm. The agglomeration process proceeded intensively at a discharge of 1 100 – 1 200 mm Hg, the layer temperature reached over 1 200 ˚C. The resulting product (agglomerate) was divided into size classes of 0 - 5 mm, 5 - 10 mm and +10 mm. The output and the chemical composition of the agglomerate are shown in Table 2. The duration of the agglomeration process averaged 25 - 28 minutes.

When determining the strength of the agglomerate, using the method of double dropping from a height of 2 m onto a steel plate (according to GOST 25471 - 82), it was found that the resulting agglomerate in structure had high mechanical properties in terms of strength (Figure 3). Fractional and chemical composition is shown in Table 3. The total weight of the agglomerate without fines was 845 g.

To confirm the results obtained, experiments on the agglomeration of the same nickel ores were repeated using Altai coke as a reductant with the following technical composition, %: solid Carbon – 85,24 ($C_{sol.}$); Volatiles - 2,7 (V_{daf}); Ash – 10,11 (A_c); Moisture– 1,32 (Wp), with a discharge of 1200 mm Hg, the duration of the sintering process averaged 19 - 21 minutes. The resulting product (agglomerate) was also divided into size classes, as in the previous process, the yield and chemical composition are shown in Table 4.

When studying the strength of the agglomerate, the method of dropping the agglomerate from a height of 2

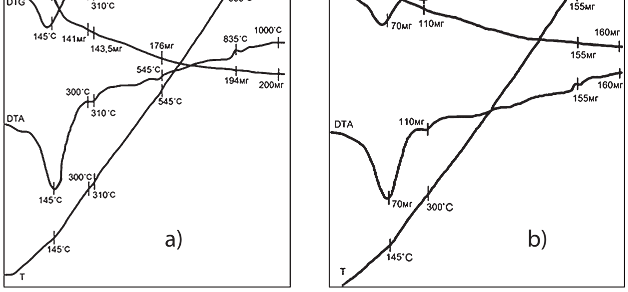

Figure 1 Thermograms of nickel ores:
a) - sample № 1, b) - sample № 2
DTA - differential thermal analysis;
TG - thermogravimetry, DTG - differential thermogravimetry

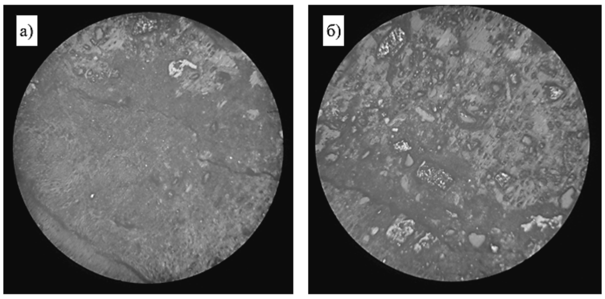

Figure 2 Microstructure of oxidised ore from the Batamshinskoye deposit, a) × 50; b) × 500

m (GOST 25471 - 82) was used too. The resulting agglomerate had higher mechanical properties in terms of strength than the agglomerate obtained from nickel ores and semicoke (Figure 4). Fractional and chemical composition is shown in Table 5. The total weight of the agglomerate without fines was 970 g.

The maximum nickel content in the sintering tests carried out was up to 1,47 %, and the chromium content was 6,88 %. The resulting agglomerate had high strength in both cases.

CONCLUSIONS

One of the possible ways to involve Kazakhstani nickel ores in the metallurgical treatment is the development of technologies for integrated processing with the production of nickel-chromium-containing cast iron. Further treatment of cast iron will allow smelting stainless steel grades without the use of ferrochrome and ferronickel [10 - 12]. Currently, due to the lack of own production, industrial enterprises of the Republic of Kazakhstan are forced to import the entire class of stainless, contracid, hot-resistant, ball-bearing, spring, tool and hardware steel grades. These steel grades are used as fittings for oil refineries, cone pumps operating under pressure in hot oil environments, equipment for nitric and phosphoric acids and parts for chemical engineering instruments, which indicates the need to create our own production of stainless steel grades in Kazakhstan.

Smelting nickel cast iron using traditional technologies is carried out in blast furnaces. We propose to use ore smelting furnaces using various types of reducing agents such as coke and coal. The resulting semi-product (nickel cast iron) will be further used for smelting special steel grades. Smelting of nickel-chromium-containing pig iron was carried out in a high-temperature Tamman furnace using several types of reducing agents (metallurgical coke and coal). The results of the experimental melt heats are shown in Table 6.

Experimental melts have shown the fundamental possibility of producing cast iron with a nickel content of 3 - 5 %, suitable for melting certain types of special alloyed steel grades.

Table 2 **Fractional and chemical composition of the sinter obtained from nickel ores and semi-coke / wt. %**

Fraction / mm	Output / %	Content / %					Recovery rate / %		
		Ni	Fe	Cr	C	Ni/Fe	Ni	Fe	Cr
+0 - 5	33	1,26	16,7	4,70	6,01	0,07	29,1	29,5	56,5
+5 - 10	2	1,46	20,0	5,02	0,38	0,07	2,31	2,43	4,14
+10	65	1,47	19,0	1,62	0,24	0,08	68,6	68	39,3
Σ	100	1,40	18,3	2,69	2,11	0,08	100	100	100
+5 - 10 and +10	67	1,47	19,0	1,73	0,24	0,08	70,9	70,4	43,5

Table 3 **The strength characteristics of the agglomerate after being dropped from a height of 2 m / wt. %**

Fraction / mm	Output / %	Content / %					Recovery rate / %		
		Ni	Fe	Cr	C	Ni/Fe	Ni	Fe	Cr
+0 - 5	19	1,44	18,5	6,24	0,68	0,08	18,9	19,1	38,8
+5 - 10	6	1,45	19,0	6,88	0,14	0,08	5,95	6,14	13,4
+10	75	1,44	18,2	1,94	0,28	0,08	75,1	74,7	47,8
Σ	100	1,44	18,3	3,05	0,35	0,08	100	100	100
+5 - 10 and +10	81	1,44	18,2	2,30	0,27	0,08	81,1	80,9	61,2

Table 4 **Fractional and chemical composition of the agglomerate obtained from nickel ores and coke (Altai)**

Fraction / mm	Output / %	Content / %					Recovery rate / %		
		Ni	Fe	Cr	C	Ni/Fe	Ni	Fe	Cr
+0 - 5	31,7	1,18	15,9	4,29	11,8	0,07	28,3	29,1	34,1
+5 - 10	1,2	1,37	18,7	1,78	1,71	0,07	1,16	1,21	0,50
+10	67,1	1,39	18,0	3,89	0,34	0,08	70,5	69,7	65,4
Σ	100	1,32	17,34	3,99	3,99	0,076	100	100	100
+5 - 10 and +10	68,3	1,39	18,01	2,85	0,36	0,077	71,7	70,9	65,9

Table 5 **The strength characteristics of the agglomerate after being dropped from a height of 2 m**

Fraction / mm	Output / %	Content / %					Recovery rate / %		
		Ni	Fe	Cr	C	Ni/Fe	Ni	Fe	Cr
+0 - 5	10,8	1,40	18,0	6,80	0,96	0,08	33,1	32,6	49,7
+5 - 10	2	1,41	18,5	1,86	2,36	0,08	33,3	33,5	13,6
+10	87,2	1,42	18,7	5,02	0,29	0,07	33,6	33,9	36,7
Σ	100	0,46	5,97	1,48	0,39	0,08	100	100	100
+5 - 10 and +10	89,2	0,34	4,51	0,83	0,32	0,08	66,9	67,4	50,3

Table 6 **The chemical composition of smelting products**

Materials	Content / %							
Cast iron	Ni	Cr	Fe	Si	C	S	P	Co
Sample 1	3,68	4,50	73,8	7,21	4,38	0,022	0,08	0,290
Sample 2	3,2	4,4	62,50	21,58	2,51	-	0,21	0,15
Sample 3	2,46	21,61	39,69	20,28	2,24	0,039	0,32	-
Sample 4	6,54	2,65	73,2	2,22	5,07	0,32	0,033	0,13
Slag	NiO	Cr_2O_3	FeO	SiO_2	Al_2O_3	CaO	MgO	CoO
Sample 1	0,2	0,16	3.22	43,37	4,24	41,12	8,68	0,023
Sample 2	0,069	0,54	4,62	42,25	3,61	5,27	14,88	0,013
Sample 3	1,33	4,32	2,64	43,28	4,58	29,59	9,26	-
Sample 4	0,15	1,05	5,26	69,12	3,94	2,38	10,34	-

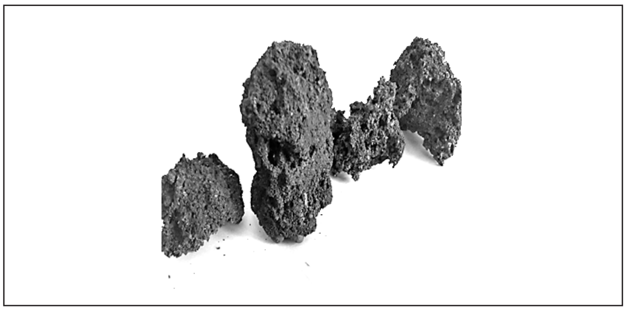

Figure 3 Agglomerate obtained from

Figure 4 Agglomerate obtained from chromium-nickel ore and semi-coke chromium-nickel ore and Altai's coke

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