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STUDY OF NICKEL BRIQUETTES BY THERMOGRAPHIC METHOD

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The results of thermogravimetric studies of nickel concentrate (briquettes) with the establishment of its characteristic features are presented. The study of nickel concentrate with different reducing agents showed the thermographic possibility of involving them in metallurgical processing. The values of the activation energy in the process of thermal studies are determined.

Key words: Nickel briquette, agglomeration, smelting, physico-chemical transformations, activation energy.

INTRODUCTION

As at know, the oxidized nickel ore in the bulk consists of a fine fraction and therefore can not be used in the mine furnace and electric smelting. One of the types of preparation of nickel ores for smelting is pelletizing. In metallurgical practice, there are many different methods of pelletizing fine materials, but the most common are three methods: briquetting, agglomeration and pellet production. Each method has its own requirements for the preparation of the material, while affecting the physico-chemical conditions of the pelletizing process and the quality characteristics of the final product [1-5].

RESEARCH METHODOLOGY

Briquetting is the process of thermochemical processing of small and weakly structured ores, concentrates and production waste in order to obtain briquettes from them-pieces of geometrically correct uniform shape and constant dimensions. According to modern technology, briquetting can be carried out with the use of binding materials and without them [6-8].

RESULTS RESEARCH AND DISCUSSION

In order to define the possibility of settling nickel ore of the 0 - 3 mm fraction, briquetting studies were carried out on a laboratory press unit with a maximum permissible pressure of 250 kgf / cm^2. To study the pressing process, nickel ore with a chemical composition % ($Ni_{general}$ - 1,23; $Fe_{general}$ - 14,38; $Cr_{general}$ - 1,69; SiO_2 - 51,57; MgO - 3,52; Al_2O_3 - 1,87), mixed with long - flame coal, with a technical composition (C - 49,99; V^c - 35; A^c - 9,85; W - 4,8) was used [8].

Liquid glass was used as a binding material for briquetting. The consumption of the binder material (liquid glass), depending on the silicate module, varied in the range of 8 - 10 % by weight. As a result, nickel ore briquettes with a diameter of 15 - 20 mm and a height of 15 - 25 mm were obtained (Figure 1) with a compressive strength of 50 - 60 kg / briquette. The technological characteristics of the manufactured briquettes are summarized in Table 1.

Table 1 **Technological parameters and quality of briquettes obtained from nickel ore**

Parameters and indicators	Units of measurement	Indicators
1. Raw briquettes:		
- crush resistance	/ kilo / briquette	10 - 20
- solid binder consumption	/ %	8 - 10
2. Drying of briquettes:		
- temperature	/ ˚C	250 - 300
- drying time	/ hour	1 - 2
3. Ready-made briquettes:		
- crush resistance	/ kilo / briquette	50 - 60
- impact strength	/ %	60,0
- abrasion resistance	/ %	25 - 30
- diameter of briquettes	/ mile	1,5 - 2,0

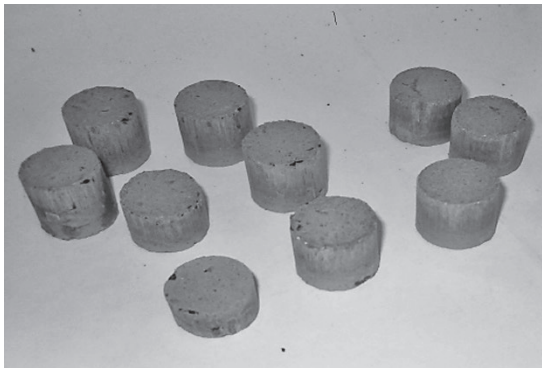

Figure 1 Briquettes obtained from nickel ore

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The resulting briquettes were divided into size classes to determine the yield of the suitable fraction when dropped from a height of 2 meters, which is acceptable for metallurgical processing. The fractional and chemical composition of the briquettes is shown in Table 2.

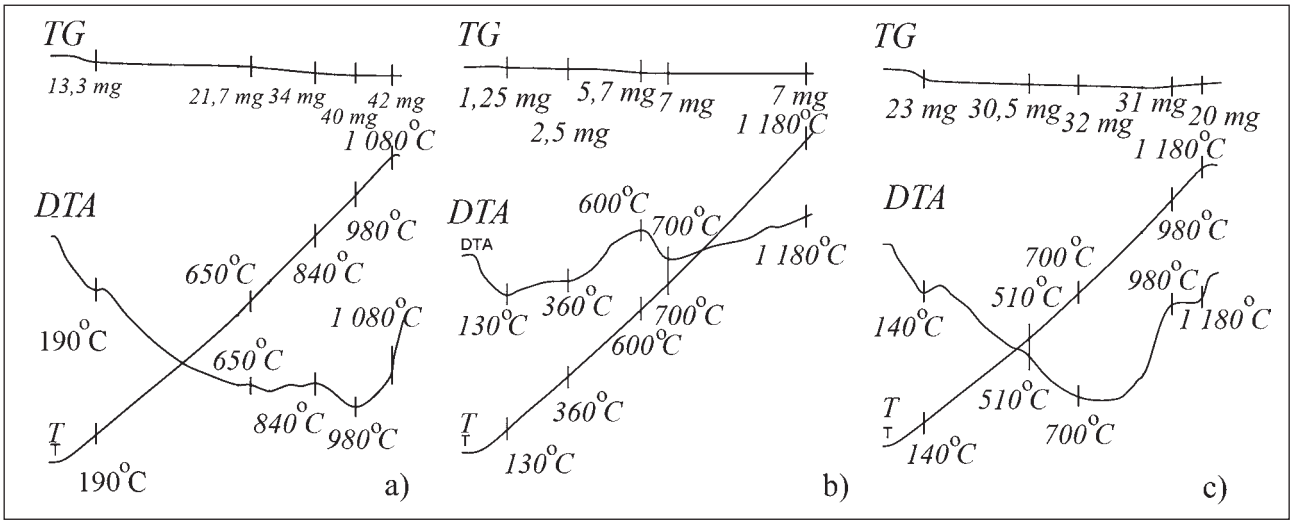
As can be seen from Table 2, the main share of the obtained briquettes (> 96 %) is a fraction of + 5 mm, which fully meets the requirements for charge materials according to the size class.

Table 2 **Fractional composition of nickel ore and long-flame coal briquettes when dropped from a height of 2 m**

Fraction / mile	Quit / %	Quit / gr	Contents / %		
+0 - 0,5	0,23	0,16			
+0,5 - 1,5	0,45	0,31			
+1,5 - 3	0,92	0,62			
+3 - 5	0,83	0,57	1,23	1,69	14,38
+5	97,57	66,7			
Σ	100	68,36			
+3-5 and +5	98,4	67,27			

In addition to the metallurgical estimates of nickel ores, we studied the physical and chemical properties of briquettes under heating [9-11]. The materials were studied on a derivatograph of the system F. Paulik, J. Paulik, L. Erdei Derivatograph Q = 1 000 in the temperature range 20 - 1 400 ºC with a heating rate of 10 ºC / min. The temperature in the furnace was measured by a platinum-platinum-rhodium thermocouple [9,10]. The studies were carried out in an oxidizing atmosphere. On the derivatograms, these analyses are shown in the form of thermogravimetric (TG) and differential-thermoanalytic (DTA) curves [12, 13]. The material under study consisted of: briquettes 1 (ore+coke), briquettes 2 (ore+coal) and briquettes 3 (ore+silicon-aluminum reducing agent) (Figure 1 a, b, c). Table 3 below shows the chemical and technical compositions of the materials under study.

The processes occurring in the nickel briquette 1 (Figure 2, a) have five kinks. At a temperature of 190 °C, the first endothermic effect is manifested, accompanied by the removal of hygroscopic and adsorbed moisture with a decrease in the sample mass by 13,3 mg. The second weakly expressed exothermic effect, observed at a temperature of 650 °C, is due to the completion of the release of hydrate moisture and the complete removal of volatile components. The total weight loss at this temperature was 21,7 mg. In addition to these processes, in the temperature range of 500 - 600 °C, some physical and chemical transformations occur - the decomposition of serpentine ($3MgO{\cdot}2SiO_2{\cdot}2H_2O$) and siderite ($FeCO_3$). A further increase in temperature leads to the interaction of the nickel briquette with the reducing agent. At a temperature of 840 °C, a third pronounced exothermic effect is observed at a decrease in



a) nickel briquette (ore + coke), b) nickel briquette (ore + coal), c) nickel briquette (ore + silicon-aluminum reducing agent)

Figure 2 Derivatograms of nickel briquettes

Table 3 **Chemical and technical compositions of the studied materials [9]**

Materials	Chemical composition / %					
	$Ni_{general}$	$Fe_{general}$	$Cr_{general}$	SiO_2	MgO	Al_2O_3
Nickel ore	1,23	14,38	1,69	51,57	3,52	1,87
Silicon-aluminum reducing agent	Al	Si	Cr	Fe		
	14,41	25,11	36,92	16,12		
	Technical staff / %					
	A^c	W	V^c	C		
Coke	19,38	2,44	6,19	73,86		
Coal	9,85	4,8	35	49,99		

* where A^c - ash content of coal (^{C} on dry weight); V^c - volatile components; W - humidity

Table 4 **Values of the apparent activation energy determined by the tangent of the slope angle of the direct dependence lg Δt-1/T**

№	Material	The equation	Coefficient of correlation R	Eact / kJ/mol	Temperature range / ° C
1	Nickel briquette (ore + coke)	lnΔt = -461,29 / T + 11,21	0,9904	8,832	130 - 190
		lnΔt = -2244,4 / T + 25,27	0,9136	42,975	610 - 650
		lnΔt = -474,66 / T + 5,41	0,9658	9,088	740 - 840
2	Nickel briquette (ore + coal)	lnΔt =-66,58 / T + 3,29	0,9441	1,274	10 -130
		lnΔt =-512,95 / T + 8,98	0,9707	9,822	300 - 360
		lnΔt = -301,86 / T + 4,79	0,8002	5,780	480 - 600
		lnΔt = -1780,5 / T + 20,06	0,9766	34,093	620 - 700
3	Nickel briquette (ore + AHS)	lnΔt = -70,43 / T + 3,34	0,9433	1,348	20 - 140
		lnΔt = -1798,3 / T + 23,5	0,9999	34,434	480 - 510
		lnΔt = -277,54 / T + 4,59	0,8694	5,314	480 - 700
		lnΔt = -973,81 / T + 9,38	0,9475	18,646	880 - 980

the sample mass by a total of 34 mg. This effect corresponds to the decomposition of the mineral nontronite (Fe, Al) 2 $[Si_4O_{10}(OH]_2 \cdot nH_2O)$. When Gorenje material was heated to 1 080 °C, the fourth and fifth endothermic effects were recorded, characterized by the combustion of solid carbon (at a temperature of 980 °C) with the appearance and establishment of the main components of natural minerals (Fe, Al) $2[Si_4O_{10}(OH]_2 \cdot nH_2O$; Fe_2O_3; $FeCr_2O_4$) (at a temperature of 1 080 °C). The total weight loss at these temperatures is 40 mg and 42 mg, respectively.

When considering the DTA curve of the derivatograms of nickel briquette 2 (nickel ore+coal) As you can see in Figure 2 (b), there are a number of effects, which allows you to highlight the most important temperature intervals. The first endothermic effect was observed at a temperature of 130 °C with a mass decrease of 1,25 mg. This effect describes the complete removal of hygroscopic and adsorbed moisture from the coke. Further, at temperatures of 360 °C and 600 °C, the second endothermic and third exothermic effects were observed, corresponding to the burning of volatiles and the decomposition of the serpentine mineral ($3MgO \cdot 2SiO_2 \cdot 2H_2O$). In addition to these transformations, the decomposition of siderite $FeCO_3$ can be observed at a temperature of 560 °C. Total weight loss at these temperatures was 2,5 mg and 5,7 mg, respectively. The fourth endothermic effect at a temperature of 700 °C leads to the beginning of recovery processes with a decrease in total weight by 7 mg. A further increase in temperature to 1 180 °C shows the formation of a fifth weak endothermic effect with a total weight loss of 7 mg. This curve indicates the partial formation of the main phases of minerals (Fe, Al) $2[Si_4O_{10}(OH]_2 \cdot nH_2O$; Fe_2O_3; $FeCr_2O_4$).

The derivatogram of a nickel briquette with a silicon-aluminum reducing agent (Figure 2 (c)) shows two endothermic and two exothermic effects that characterize the course of complex physicochemical transformations in the material under study. The first endothermic and second exothermic inflection, which took place at temperatures of 140 °C and 510 °C, were responsible for the removal of hygroscopic moisture from the ore and the release of structured moisture with a total weight loss of 23 mg and 30,5 mg, respectively. The third pronounced endothermic effect (at a temperature of 700 °C), apparently, corresponds to the rearrangement of the lattices of the intermetallides of the silicon-aluminum reducing agent with a weight loss of up to 32 mg. An increase in temperature to 980 °C leads to an increase in the DTA curve (steep maximum) of the fourth exothermic effect, corresponding to the beginning of the interaction of the ore with the reducing agent and the oxidation of the silicon-aluminum reducing agent with air oxygen. In addition, calculations were performed to determine the values of the temperature values and the deviation of the DTA curve (obtained by processing the DTA curve) from a given direction (Table 4).

CONCLUSION

The analysis of the temperature maxima and the level of the activation energy of the processes accompanied by peaks on the DTA curves of the casted nickel ores suggests that the diffusion processes occurring during heat treatment and responsible for the solid-phase hardening of sintered materials with the participation of nickel ore and reducing agents occur under more favorable conditions. Therefore, it can be concluded that the processes occurring during the heat treatment of nickel ore with different mixtures proceed at a sufficiently high speed and reach a high degree of completion at firing temperatures.

Thus, the results obtained allow us to orient ourselves in the rate of interaction reactions during the smelting of a nickel-containing alloy in industrial furnaces [14, 15]. Since nickel-containing briquettes have a low value in terms of activation energies (Table 4).

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