THERMAL ANALYSIS OF AGGLOMERATED NICKEL ORE

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ABSTRACT

Thermographic research of agglomerated nickel ore in the range of 20-1400°C is described in the paper. Experiments were made with sintered ore mixed with various reductants (coke, coal, silicon-aluminum alloy). Data obtained in the research are useful for metallurgy of nickel alloys.

1 INTRODUCTION

Nickel ore, mostly consisting of fine fractions is not suitable for direct processing in ore-smelting and shaft furnaces, which makes agglomeration of fines a necessary stage of processing. Three agglomeration methods often used in metallurgy are briquetting, sintering and pelletizing. Each method exerts specific influence on physical-chemical properties and quality of end product [1].

2 EXPERIMENTAL

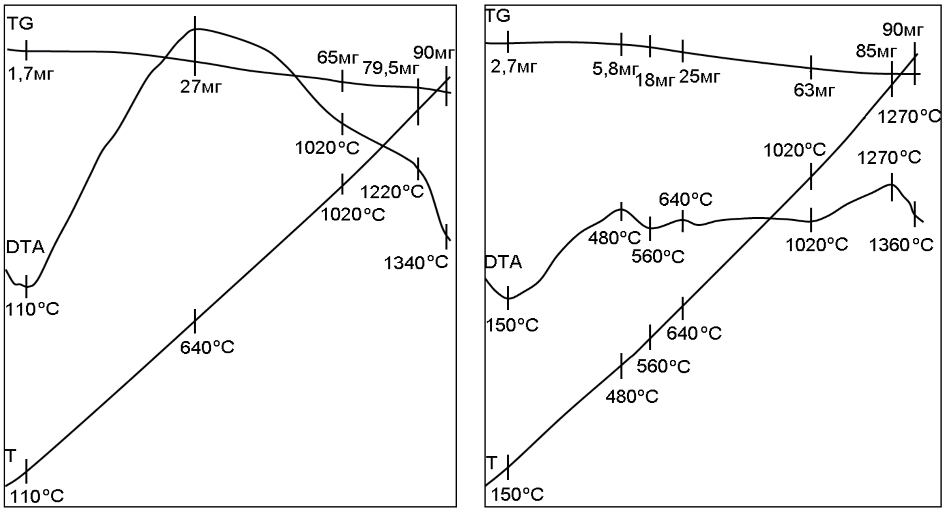
Aside from metallurgical evaluation of agglomerated nickel ore, we have conducted the research of physical-chemical properties of ore at high temperature. The research was made using thermogravimetric equipment in the range of 20-1400ºC at heating rate of 10ºC/min in oxidizing atmosphere. The temperature was measured with platinum-rhodium thermocouple. The measurements are represented in the figure 1 by thermogravimetric curves (TG) and differential-thermal analysis curves (DTA). The material studied in the research is a mixture of coke with two types of sintered ore: sample #1 (nickel ore + semi-coke) and sample #2 (nickel ore + coke). The results of chemical and proximate analyses are represented in the table 1.

Table 1: Chemical and technical composition of studied materials

Material	Chemical composition, %						
	Ni_{total}	Fe_{total}	Cr_{total}	SiO_2	MgO	Al_2O_3	Moisture
Nickel ore	1,23	14,38	1,69	51,57	3,52	1,87	8,9
	Technical composition, %						
	Ash	Moisture	Volatile	C_{solid}			
Coke	19,38	2,44	6,19	73,86			
Semi-coke	2,21	2,31	8,43	87,14			
Coke	10,11	1,32	2,7	85,24			

3 RESULTS

Four thermal effects registered during heating of sample 1 are shown in the figure 1, a). The first endothermic effect caused by absorbed moisture removal was registered at 110ºC. The loss of weight was 1,7 mg (0,89% of overall loss). The removal of hydration water lasted up to 640ºC along with the second abrupt exothermic effect. The weight loss by that moment has amounted to 27 mg (30%). In the range of 500-600ºC several transformations (caused by siderite and serpentine dissociation) took place. Further heating of sample has led to interaction of sintered ore with reductant. The third weak endothermic effect registered at 1020ºC with total weight loss of 65 mg (72,2%) was caused by oxidation of carbon. The fourth clearly visible exothermic effect at 1220ºC was accompanied by formation of basic minerals (Fe, Al)$_2$[Si_4O_{10}(OH]$_2$·nH_2O; Fe_2O_3; $FeCr_2O_4$). The weight loss at this point was 79,5 mg (88,3%).

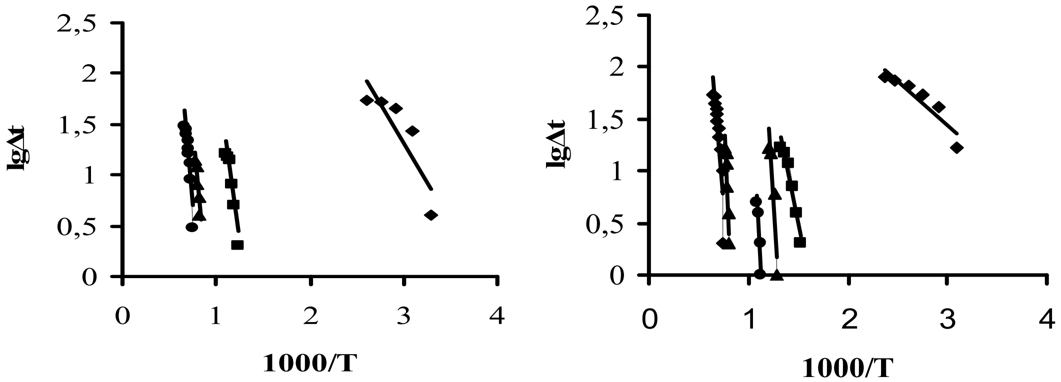


a) b)

Figure 1: Thermogravimetric curves of sintered ore

The DTA curve of sample #2 is shown in the figure 1, b).The first endothermic effect was registered at 150ºC with weight loss of 2,7 mg (3%). Further, at 480ºC and 560ºC, respectively, second and third effects, caused by oxidation of volatile matter and dissociation of serpentine ($3MgO{\cdot}2SiO_2{\cdot}2H_2O$), were registered. At 560ºC we may also see the dissociation of siderite $FeCo_3$. The weight loss values at these temperatures were 5,8 mg (6,44%) and 18 mg (20%), respectively. The fourth exothermic effect at 640ºC indicates the beginning of reduction processes with 25 mg (27,8%) weight loss. The fifth weak endothermic effect occurs at 1020ºC (weight loss is 63 mg (70%). A sharp peak at 1270ºC (sixth exothermic effect) was caused by basic minerals (Fe, Al)$_2$[Si_4O_{10}(OH]$_2$·nH_2O; Fe_2O_3; $FeCr_2O_4$) formation with total weight loss of 85 mg (94,4%).

Our research also included estimation of temperature values and calculation of DTA curve deviation. The dependence diagrams for each thermal effect were constructed in the coordinates lg *Δt - 1/T*. Further, the activation energy of the corresponding processes was determined through the tangent (slope ratio) of the dependence curve [2]. The results of linearization of ascending branch of DTA peak in the coordinates lg *Δt - 1/T* are shown in the figure 2. Based on diagrams, the activation energy of each thermal effect was determined (see table 2).



a) b)

Figure 2: Dependence of DTA peak on reciprocal temperature: a) sample 1; b) sample 2

The results of the research show that thermal processes in the sample 1 include two exothermic and two endothermic effects. According to our calculations, the values of activation energy are comparably low (see table 2). Thermal processes in the sample 2 are characterized with three exothermic and three endothermic effects that require higher activation energy (see table 2). As seen from the table 2, thermal processes in the sample 1 occur at lower temperature with lower apparent activation energy of each peak.

Table 2: Apparent activation energy determined by slope ratio of lg *Δt - 1/T* function.

Material	Equation	Correlation coefficient R	E_{act}, kJ/mole	Temperature interval, ºC
Sample 1 (nickel ore + semi-coke)	ln*Δt*=-154,33/T + 5,95	0,8803	2,955	10-110
	ln*Δt*=-664,39/T+ 8,61	0,9446	12,721	520-640
	ln*Δt*=-1091,2/T+ 9,61	0,9932	20,895	920-1020
	ln*Δt*=-1039,1/T+ 8,54	0,9103	19,896	1040-1220
Sample 2 (nickel ore + coke)	ln*Δt*=-84,43/T + 3,97	0,9279	1,616	30-150
	ln*Δt*=-468,31/T+ 7,54	0,9781	8,967	360-480
	ln*Δt*=-1327,3/T+17,34	0,9377	25,422	480-560
	ln*Δt*=-1936,7/T+21,97	0,9807	37,083	600-640
	ln*Δt*=-3040,8/T+24,85	0,9716	58,225	960-1020
	ln*Δt*=-1162,3/T+9,43	0,8889	22,255	1050-1270

The results of the research indicate the possibility of nickel- and chrome-containing iron production in electric furnaces. Low activation energy of thermal processes (and therefore lower power input of production) confirms the advantages of such method for low-grade ore processing. The data obtained in the research allow to predict the rate of reactions among the agglomerate components.

4 REFERENCES

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