

neutralized by a solution of ammonia  $\text{NH}_4\text{OH}$  with obtaining complex salt  $\text{Zn}(\text{OH})_2 \cdot \text{ZnSO}_4$  at 40 °C during 30 minutes; then the filtration and washing of a sediment by cation-polished water in the ratio L:S=7:1 and drying of a sediment at temperature 150 °C during 120 minutes are carried out. At 2<sup>nd</sup> stage carbonization of dry sediment  $\text{Zn}(\text{OH})_2 \cdot \text{ZnSO}_4$  by ammonium carbonate  $(\text{NH}_4)_2\text{CO}_3$  solution was conducted with obtaining complex salt  $\text{Zn}(\text{OH})_2 \cdot \text{ZnCO}_3$  at 40 °C during 30 minutes. At 3<sup>rd</sup> stage zinc oxide (ZnO) was obtained by thermal decomposition of the dried sediment of complex salt  $\text{Zn}(\text{OH})_2 \cdot \text{ZnCO}_3$  at 220 °C during 20 minutes. The developed technology allows to obtain zinc oxide of brand "Pure" from low-grade sulphide concentrate.

**Key words:** neutralization, carbonation, thermic decomposition, zinc oxide, X-ray analysis, atomic absorption analysis

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### COMPARATIVE ANALYSIS of TECHNOLOGY PARAMETERS of CHARGE PREPARATION for DIRECT IRON RECOVERY from SSOMDE IRON CONCENTRATE with VARIOUS REDUCTANTS

**Abstract:** The paper describes results of experimental determination of basic technology parameters of charge preparation for direct iron recovery. The charge consists of Sokolovsko-Sarbajsk Ore Mining and Dressing Enterprise (SSOMDE) iron concentrate and carbon reductants: blast-furnace coke, charcoal and carbonizate recsil. SSOMDE concentrate consists mainly of magnetite and contains, %: Fe – 66.51; FeO – 22.63;  $\text{Fe}_2\text{O}_3$  – 69.90;  $\text{SiO}_2$  – 5.05;  $\text{Al}_2\text{O}_3$  – 1.70; CaO – 3.47; MgO – 0.78; S – 0.32; P – 0.05. Reductants chemical composition is as follows, %: blast-furnace coke:  $\text{Fe}_{\text{total}}$  – 0.76; FeO – 0.05;  $\text{Fe}_2\text{O}_3$  – 1.04;  $\text{SiO}_2$  – 6.05;  $\text{Al}_2\text{O}_3$  – 2.62; CaO – 0.41; MgO – 0.46; S – 0.82; P – 0.01;  $\text{C}_{\text{solid}}$  – 88.02; charcoal:  $\text{Fe}_{\text{total}}$  – 0.58; FeO – absent;  $\text{Fe}_2\text{O}_3$  – 0.83;  $\text{SiO}_2$  – 0.10;  $\text{Al}_2\text{O}_3$  – 0.05; CaO – 0.73; MgO – 0.29; S – 0.02; P – 0.09;  $\text{C}_{\text{solid}}$  – 79.85; and carbonizate recsil: Fe – 0.28; FeO – absent;  $\text{Fe}_2\text{O}_3$  – 0.40;  $\text{SiO}_2$  – 1.56;  $\text{Al}_2\text{O}_3$  – 1.04; CaO – 0.27; MgO – 0.32; S – 0.34; P – 0.02;  $\text{C}_{\text{solid}}$  – 94.84. Calculation of initial charge composition was made by the method of Yu. Yusfin and N. Pashkov. It was found that the charge for ore-carbon pellets should contain 83.78 % of SSOMDE concentrate and 16.22 % of blast-furnace coke; 82.39 % of SSOMDE concentrate and 17.61 % of charcoal; 84.78 % of SSOMDE concentrate and 15.22 % of carbonizate recsil. Differential-thermal analysis was used to find the temperature of initial interaction of SSOMDE magnetite concentrate with carbon reductants. It was found that active recovery of iron begins at the following temperatures: blast furnace coke 930 °C, charcoal 780 °C, carbonizate recsil 840 °C. Ore-carbon pellets metallization experiments in Tamman resistance furnace (as binder – liquid glass,  $\rho = 1.20 \text{ g/sm}^3$ ) show that recsil allows getting highest degree of metallization about 83 – 90 %. Metallized with recsil pellets contained 55 – 60 % of metal iron.

**Keywords:** SSOMDE concentrate, carbon reductants, blast-furnace coke, charcoal, carbonizate recsil, ore-carbon pellets

**Introduction.** Throughout its history, the industrial coke-free metallurgy is continuously increasing the production of direct recovery iron (DRI) due to growing demand for high-quality scrap iron for steep-making needs. Shortage of scrap metal makes steel producers to use metallized pellets and sponge iron containing 85-95 % Fe; 0,5-2,0 % carbon and minimal levels of non-ferrous metals, phosphorus and sulfur. Midrex Technologies company forecasts DRI production to reach 120 million tons annually by 2020, which is 70 % higher than in 2010 [1].

Major conventional technologies of metallized products are Midrex, HYL-III and Finmet. These methods use gas from reformers as a reductant. Metallization is carried out in shaft furnaces. Metallization degree averages to 90-94 %, carbon level in the product is 0,5-3,0 %.

ITMK3 process uses coal, coke and coal wastes as reductants and the final product is pig iron regulus containing 2,5-3,5 % carbon. Recovery of ore-coal pellets is carried out in rotating bed furnaces. Metallization of ore and ore-coal pellets can be made in conveyor, annular and revolving furnaces [1, 2].

Conventional methods of deep metallization have a number of substantial disadvantages: high carbon level in the product (up to 4 %), complex and bulky equipment, high energy consumption, low reliability of certain units and parts, necessity of reductant gas reforming. Combined with shortage of scrap metal and depletion of iron ore reserves this situation calls for new technologies of high-iron metallized product, suitable for substitution of scrap iron for steelmaking industry [2].

Magnetite concentrate of SSOMDE, produced from Sokolovsky-Sarbaisky iron ore deposit, contains over 66 % Fe and is used in conventional steelmaking. However, this concentrate can be used for metallized product making.

Charcoal and blast-furnace coke are widely used in metallurgy as reductants [3].

Low impurities and well-developed porous structure provide high chemical activity of charcoal, which ensures intensive flow of recovery reactions. Disadvantages of charcoal are anisotropy of structure, low level of fixed carbon, low strength and high cost.

Compared to charcoal, blast-furnace coke has higher ash level, lower porosity and reactivity.

A substitute for charcoal is created in Kazakhstan carbonizate recsil is produced by high-speed thermal-oxidizing carbonization of Shubarkol gas coal. Advantages of carbonizate recsil are higher structural strength, high fixed carbon level, structure isotropy, developed porous structure and low cost. In terms of harmful admixtures content carbonizate recsil is comparable to charcoal. Such benefits show carbonizate recsil potential as a substitute for charcoal and blast-furnace coke [3, 4].

Fine concentrates after ore-dressing cannot be used directly in roasting and smelting due to low gas permeability of charge. Required grain size is usually 5-10 mm which is achieved by sintering or pelletizing. Each method begins with charge preparation – averaging, sieving, batching, mixing and the agglomeration itself.

The charge is a mixture of materials taken in mass or volume ratio, required to produce certain product (iron, steel, metallized product, etc.). Ratio of charge components is calculated through equations of material balance of elements or compounds contained in the initial materials. Number of equations is equal to the number of materials composing the charge. There are various charge calculation methods [2, 5, 6].

Method of F.Bazanov and I. Malkin [5] is usually used for sintering of hematite and magnetite ore. Ore and limestone ratio is calculated according to materials chemistry resulting in equation of sintering material balance. Coke fines ratio is selected using experimental data or actual fuel consumption for certain sintering plant. Next stage is the equation of charge basicity. The charge composed by the calculation results is subject to mixing, moisturizing, re-mixing, pelletizing and sintering.

Most complete method of sintering charge calculation is an integrated method of Ramm that, along with charge composition, includes basic and additional equations of material balance as well as equations of heat balance of blast-furnace smelting [6].

Charge calculation for metallized pellets covers calculation of ore-reductant ratio and consists of two equations of material balance of reductant and iron with two unknown. Charge components are dry-mixed with further pelletizing using liquid binder. Pellets roasting can be made in various furnaces – shaft furnaces, fluidized bed reactors, conveyor furnaces, annular furnaces, etc. [2].

Technology of direct iron recovery with new reductant – carbonizate recsil is being developed in Abishev Chemical-Metallurgical Institute. Processes of heat generation for recovery and iron oxides reduction are combined in one reactor and take place simultaneously.

The objective of the present work is research on determination of basic technological parameters of charge preparation that consists of SSOMDE iron concentrate and different reductants: blast-furnace coke, charcoal and carbonizate recsil and evaluation of recovery potential of recsil reductant.

**Experimental Part and Results Discussion.** *Research subjects* are SSOMDE concentrate, blast-furnace coke, charcoal and carbonizate recsil.

*Analysis methods and equipment.* SSOMDE concentrate composition was determined by chemical analysis; reductants composition – by proximate analysis; differential-thermal analysis was made in Q-1500 derivatograph in air at 18-1000 °C and heating rate of 10 °C per minute.

Initial parameters for charge composition calculation are chemical and proximate analyses of components.

It is known that moisture level of disperse material is a critical factor for its clumping speed and properties of raw pellets. Increase of moisture level to its optimum allows higher speed of nucleus formation and their growth to final pellets. Optimal moisture is specific for each kind of material and is determined experimentally in laboratory. Table 1 shows charge components chemistry.

Table 1 – Results of chemical analysis of charge components

Material	Content, %									
	Fe <sub>total</sub>	FeO	Fe <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	S	P	C <sub>solid</sub>
SSOM-DE concentrate	66,51	22,63	69,90	5,05	1,70	3,47	0,78	0,32	0,05	-
carbonizate recsil	0,28	-	0,40	1,56	1,04	0,27	0,32	0,34	0,02	94,84
blast-furnace coke	0,76	0,05	1,04	6,05	2,62	0,41	0,46	0,82	0,01	88,02
charcoal	0,58	-	0,83	0,10	0,05	0,73	0,29	0,02	0,09	79,85

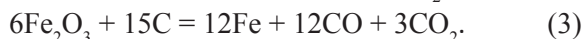
According to X-ray phase analysis SSOMDE concentrate is represented by magnetite. Theoretical composition of magnetite is 31 % of FeO and 69 % of Fe<sub>2</sub>O<sub>3</sub>. Excessive Fe<sub>2</sub>O<sub>3</sub> level (19,53 %) indicates the presence of maggemite γ-Fe<sub>2</sub>O<sub>3</sub>. Unlike other iron oxides maggemite and magnetite have very close interplanar spacing which greatly complicates their identification in the X-ray diagrams. Concentrate humidity is 0,88 %. Proximate analysis of reductants is shown in the table 2.

Table 2 – Proximate analysis of reductants

Material	Content, %		
	A <sup>d</sup>	W <sub>t</sub> <sup>r</sup>	V <sup>daf</sup>
blast-furnace coke	11,74	0,41	0,24
charcoal	2,15	8,10	18,00
carbonizate recsil	3,85	1,91	1,31

Charge composition was calculated using the method of Yu. Yusfin and N. Pashkov [2].

For CO/CO<sub>2</sub> ratio equal to 4 the process of iron oxides recovery with carbon can be written as follows:



Balance of fixed carbon in the charge:

$$Y \cdot C_{\text{fixed}} = X \{ b_1(\text{Fe}_2\text{O}_3)_X + \eta_{\text{met}} b_2 [0,9(\text{Fe}_2\text{O}_3)_X + (\text{FeO})_X] \} + \\ + Y \{ b_1(\text{Fe}_2\text{O}_3)_Y + \eta_{\text{met}} b_2 [0,9(\text{Fe}_2\text{O}_3)_Y + (\text{FeO})_Y] \} + \\ + Z \{ b_1(\text{Fe}_2\text{O}_3)_Z + \eta_{\text{met}} b_2 [0,9(\text{Fe}_2\text{O}_3)_Z + (\text{FeO})_Z] \} + \\ + D \{ b_1(\text{Fe}_2\text{O}_3)_D + \eta_{\text{met}} b_2 [0,9(\text{Fe}_2\text{O}_3)_D + (\text{FeO})_D] \} + C_{\text{residual}}$$

where 0,9 – mass ratio of FeO and Fe<sub>2</sub>O<sub>3</sub>; X – iron ore consumption, kg/100 kg of metallized product; Y – reductant consumption, kg/100 kg of metallized product; Z – flux consumption, kg/100 kg of metallized product; D – additives consumption, kg/100 kg of metallized product; Fe<sub>2</sub>O<sub>3</sub>, FeO, etc. – content of respective compounds and elements in the charge, unit part; C<sub>residual</sub> – residual level of carbon in metallized product, kg/100 kg of metallized product; C<sub>fixed</sub> – fixed carbon level in reductant, unit part; b<sub>1</sub> = 0,0625; b<sub>2</sub> = 0,139.

Balance of iron in the charge:

$$X \{ 1 - [a_1(\text{Fe}_2\text{O}_3)_X + \eta_{\text{met}} a_2 [0,9(\text{Fe}_2\text{O}_3)_X + (\text{FeO})_X] + kS_X + \\ + (\text{loss on ignition})_X + (M_{\text{Zn,Mn}})_X \} \} + Y \{ 1 - [a_1(\text{Fe}_2\text{O}_3)_Y + \\ + \eta_{\text{met}} a_2 [0,9(\text{Fe}_2\text{O}_3)_Y + (\text{FeO})_Y] + kS_Y + V_{Y^+} + (M_{\text{Zn,Mn}})_Y \} \} + \\ + Z \{ 1 - [a_1(\text{Fe}_2\text{O}_3)_Z + \eta_{\text{met}} a_2 [0,9(\text{Fe}_2\text{O}_3)_Z + (\text{FeO})_Z + \\ + kS_Z + (\text{loss on ignition})_Z + (M_{\text{Zn,Mn}})_Z] \} \} + \\ + D \{ 1 - [a_1(\text{Fe}_2\text{O}_3)_D + \eta_{\text{met}} a_2 [0,9(\text{Fe}_2\text{O}_3)_D + (\text{FeO})_D + \\ + kS_D + (\text{loss on ignition})_D + (M_{\text{Zn,Mn}})_D] \} \} = 100, \quad (5)$$

where k – desulphurization degree during metallization (usually averaging 30-50 %); M<sub>Zn,Mn</sub> – amount of Zn, Mn, etc. compounds removed during metallization; a<sub>1</sub> = 0,1625; a<sub>2</sub> = 0,361 [5].

Initial conditions are: metallization degree η<sub>met</sub> = 1, desulphurization degree k = 0,3, residual level of carbon 1,0 %.

Equations of fixed carbon balance and iron balance for pellets containing SSOMDE concentrate and recsil result in the following equation system:

$$-0,1626X + 0,9469Y = 1; \\ 0,5742X + 0,9248Y = 100. \quad (6)$$

Solution of this system shows that the charge for pellets should contain 84,78 % of SSOMDE concentrate and 15,22 % of carbonizate recsil.

Similar calculations were made for charge mixtures with blast-furnace coke and charcoal.

Charge compositions for above reductants are shown in the table 3.

Table 3 – Charge composition for ore-carbon pellets

Material	Content, %		
	SSOMDE concentrate and carbonizate recsil	SSOMDE concentrate and blast-furnace coke	SSOMDE concentrate and charcoal
SSOMDE concentrate	84,78	83,78	82,39
carbonizate recsil	15,22	-	-
blast-furnace coke	-	16,22	-
charcoal	-	-	17,61

According to [7, 8], metallization degree depends more on concentrate grain size than on reductant size.

Use of 0,06 mm concentrate instead of 0,1 mm allowed to increase metallization degree from 59,1 % to 76,6 %. Influence of reductant fraction was insignificant for the concentrate grain size below 0,06 mm. Use of coke size of 0,075 mm instead of 0,15 mm allowed to increase metallization degree from 76,6 % to 78,8 %. Thus, use of finely ground materials improves recovery process. It was finally found that the charge should contain at least 85 % of concentrate and reductant both ground to 0-0,074 mm.

When using reductants containing high level of volatile matter (charcoal, brown coal semi-coke, coke, etc.) it is necessary to consider volatiles contribution to the recovery process. If such volatiles are emitted at low temperatures (below 300-400 °C) their role as reductants is insignificant.

The temperature of initial interaction of magnetite concentrate with reductants was determined by differential-thermal analysis. In the figure there are represented derivatograms of pure concentrate as well as its mixtures with three mentioned reductants.

The curve of pure SSOMDE concentrate (a) shows diffused endothermic effect with maximum at 140 °C, caused by removal of adsorption moisture, corresponding to mass decrease on TG curve. Exothermic effect at 370 °C is oxidation of FeO on the magnetite surface with formation of thin film of hematite  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>. Mass increase begins from this point and continues throughout the heating in the range of 580-1000 °C which is explained by oxidation of remaining magnetite to maghemite  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub>. Exothermic effect at 505 °C is a transition of cubic  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> into trigonal modification [9].

Derivatograms of charge mixtures containing concentrate and one of reductants (b, c, d) have evident endothermic effects due to adsorption moisture removal: 100-240 °C for carbonizate recsil and 130 °C for charcoal and dehydration at 230-410 °C for blast-furnace coke.

At 500 °C we can see emission of volatiles from carbonizate recsil, at 612 and 525 °C – the same for blast-furnace coke and charcoal, respectively. Parallel to that, at 500–840 °C (b), 612-930 °C (c), 560-780 °C (d) we can see partial gasification of carbon with recovery of iron oxides. At 840 °C (b), 930 °C (c) и 780 °C (d) and higher there is abrupt endothermic effect caused by intensification of recovery processes, which requires greater amount of heat [8].

Evaluation of reductants quality made previously allowed to determine their reactivity at 1273 K, ml/(g·s): 0,27 for blast-furnace coke; 2,0-3,0 for carbonizate recsil and 8,1 for charcoal [10]. Derivator-

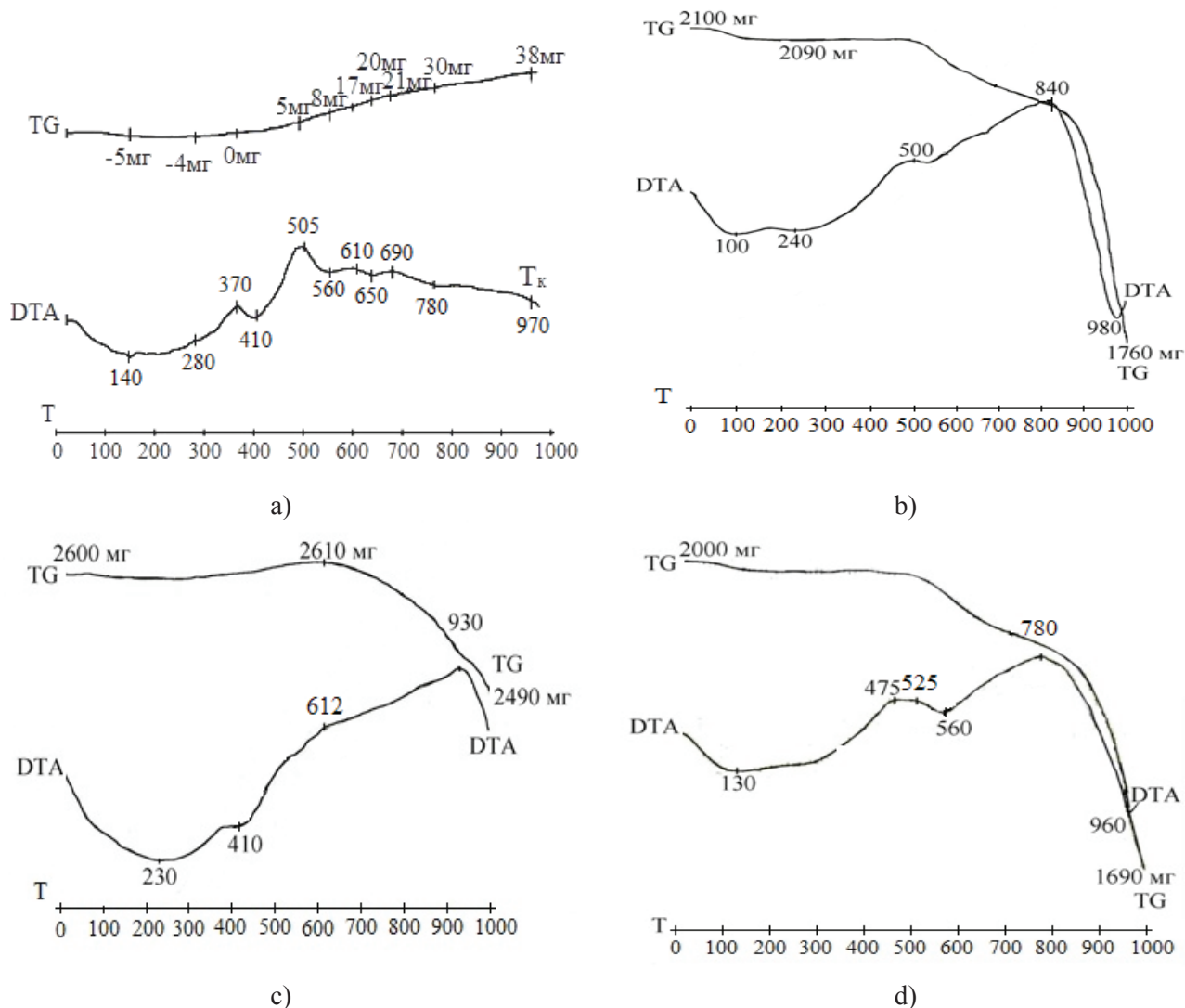
grams of concentrate mixtures with reductants show that higher reactivity of reductant causes lower temperature of recovery beginning. Active recovery of iron oxides in oxidative atmosphere begins at 930 °C for blast-furnace coke; 840 °C for carbonizate recsil and 780 °C for charcoal, which corresponds to the data shown in [11].

Research was made on pelletizing the charge mixtures with waterglass ( $\rho = 1,2 \text{ g/cm}^3$ ). Pellets size was -15+10 mm, moisture level 9-12 %. After air drying moisture level decreased to 0,89 - 1,70 %, compression strength was 11,6-14,0 kg per pellet, impact strength for 1,5 m height was 7-8 drops.

Preliminary metallization experiments were made in Tamman resistance furnace at 1200 and 1300 °C, heating duration 3-5 min [12]. Phase composition of metallized product was determined by X-ray phase analysis. Pellets with charcoal had low strength after roasting at 1200 °C, with most pellets broken. At 1300 °C peripheral area of whole pellets was formed by sponge iron while the core remains unrecovered due to low temperature or short time of recovery. Regardless of temperature and heating duration, pellets contained Fe<sub>met</sub>, Fe<sub>3</sub>O<sub>4</sub> and Fe<sub>2</sub>O<sub>3</sub>. Metallization degree was below 50 %. Further increase of duration or/and temperature is unpractical due to high energy consumption. Besides, serious disadvantage of charcoal is its high cost.

Roasting of pellets with blast-furnace coke at 1200 and 1300 °C resulted in homogenous regulus of sponge iron of initial shape, without cracks and destruction, with oxide film covering metallized product inside. Regardless of heating duration pellets roasted at 1200 °C contained Fe<sub>met</sub>, Fe<sub>3</sub>O<sub>4</sub> and FeO. Pellets roasted at 1300 °C contained Fe<sub>met</sub>, Fe<sub>3</sub>O<sub>4</sub>, FeO and minor amount of Fe<sub>2</sub>C. Compression strength was over 20 kg per pellet, impact strength over 20 drops from 1,5 m, metallization degree over 80 %. Pellets are suitable for further smelting. However, shortage of coking coal and high ash level significantly reduce practical value of blast-furnace coke for this process.

Roasting of pellets with recsil at 1200 and 1300 °C also resulted in homogenous regulus of sponge iron of initial shape, without cracks and destruction. Regardless of heating duration pellets roasted at 1200 °C contained Fe<sub>met</sub> and that roasted at 1300 °C contained Fe<sub>met</sub> and minor amount of Fe<sub>2</sub>C. Pellets have thin oxide film covering metallized product inside. Metallization degree was 83-90 %. Compression strength was over 20 kg per pellet, impact strength over 20 drops from 1,5 m.



a –SSOMDE concentrate; b – concentrate + carbonizate recsil; c – concentrate + blast-furnace coke; d – concentrate + charcoal.

Figure – Differential-thermal analysis curves

**Conclusions.** Evaluation of technological parameters of charge preparation containing SSOMDE iron concentrate and different reductants: blast-furnace coke, charcoal and carbonizate recsil was made in the work.

Moisture levels and grain size of initial materials were studied. DTA analysis showed that active recovery of iron oxides begins at 930 °C for blast-furnace coke; 840 °C for carbonizate recsil and 780 °C for charcoal. According to calculations the charge for ore-carbon pellets should contain 83,78 % of SSOMDE concentrate and 16,22 % of blast-furnace coke; 82,39 % of SSOMDE concentrate and 17,61 % of charcoal; 84,78 % of SSOMDE concentrate and 15,22 % of carbonizate recsil. Preliminary experimental research show that carbonizate recsil would

have the highest efficiency as a reductant for this process. After roasting at 1200 °C metallization degree was 83-90 %, compression strength was over 20 kg per pellet, impact strength over 20 drops from 1,5 m.

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## ТҮЙІНДЕМЕ

Мақалада тікелей қалпына келтірілген темірді алу үрдісі үшін құрамында көмірі бар қалыпқа келтіргіштер: жаңа рексил карбонизаты, ағаш көмірі мен доменді кокс және ССГПО концентратынан тұратын шихталарды дайындаудағы негізгі технологиялық параметрлерін анықтау бойынша тәжірибелік зерттеу нәтижелері ұсынылған. ССГПО концентраты магнетитпен ұсынылды және құрамы %: Fe<sub>ж</sub> - 66,51; FeO - 22,63; Fe<sub>2</sub>O<sub>3</sub> - 69,90; SiO<sub>2</sub> - 5,05; Al<sub>2</sub>O<sub>3</sub> - 1,70; CaO - 3,47; MgO - 0,78; S - 0,32; P - 0,05. 0,05 тұрды. Доменді кокс %: Fe<sub>ж</sub> - 0,76; FeO - 0,05; Fe<sub>2</sub>O<sub>3</sub> - 1,04; SiO<sub>2</sub> - 6,05; Al<sub>2</sub>O<sub>3</sub> - 2,62; CaO - 0,41; MgO - 0,46; S - 0,82; P - 0,01; C<sub>к</sub> - 88,02. Ағаш көмірі %: Fe<sub>ж</sub> - 0,58; FeO – анықталмаған; Fe<sub>2</sub>O<sub>3</sub> - 0,83; SiO<sub>2</sub> - 0,10; Al<sub>2</sub>O<sub>3</sub> - 0,05; CaO - 0,73; MgO - 0,29; S - 0,02; P - 0,09; C<sub>к</sub> - 79,85. Рексил карбонизаты құрамы %: Fe<sub>ж</sub> - 0,28; FeO – анықталмаған; Fe<sub>2</sub>O<sub>3</sub> - 0,40; SiO<sub>2</sub> - 1,56; Al<sub>2</sub>O<sub>3</sub> - 1,04; CaO - 0,27; MgO - 0,32; S - 0,34; P - 0,02; C<sub>к</sub> - 94,84. Шихталық материалдардың шығысын Ю.С Юсфинның және Н.Ф.Пашковтың ұсынған әдістемесі бойынша өткізді. Кен-көмірлі түйіршіктердің шығысын дайындау үшін шихта 83,78 % ССГПО концентраты мен 16,22 % доменді коксы, 82,39 % ССГПО концентраты мен 17,61 % ағаш көмір, 84,78 % ССГПО концентраты мен 15,22 % рексилден тұруы керектігін көрсеткен. ДТА әдісі арқылы қалыпқа келтіргіштермен магнетитті ССГПО концентратының арақатынас бастауының температуралары анықталған. Темір оксидтерін қатты көміртекпен белсенді қалыпқа келтіру: ағаш көмірі – 780 °С, рексил – 840 °С, доменді кокс үшін – 930 °С температурада басталатыны айқындалған. Таммана пешінде кен-көмірлі түйіршіктерге (байланыстырушы ретінде сұйық шыны) металдандыру жүргізуде қалыпқа келтіргіш ретінде рексил карбонизатын пайдалану анағұрлым тиімдірек екені анықталған, алынған металдандырылған түйіршіктер 55 – 60 % Fe<sub>мет...</sub> -ден тұрды, ал металдандыру деңгейі 83 – 90 % құрады.

**Түйінді сөздер:** ССГПО концентраты, құрамында көмірі бар қалыпқа келтіргіштер, доменді кокс, ағаш көмірі, рексил карбонизаты, кен-көмірлі түйіршіктер

## РЕЗЮМЕ

В статье представлены результаты экспериментальных исследований по определению основных технологических параметров подготовки шихты, состоящей из концентрата ССГПО (Соколовско-Сарбайского горно-обогатительного производственного

объединения) и углеродсодержащих восстановителей: доменного кокса, древесного угля и нового карбонизата рексила, для процесса получения железа прямого восстановления. Концентрат ССГПО представлен магнетитом и содержал, %:  $Fe_{общ}$  - 66,51;  $FeO$  - 22,63;  $Fe_2O_3$  - 69,90;  $SiO_2$  - 5,05;  $Al_2O_3$  - 1,70;  $CaO$  - 3,47;  $MgO$  - 0,78;  $S$  - 0,32;  $P$  - 0,05. Химический состав восстановителей, %: доменный кокс:  $Fe_{общ}$  - 0,76;  $FeO$  - 0,05;  $Fe_2O_3$  - 1,04;  $SiO_2$  - 6,05;  $Al_2O_3$  - 2,62;  $CaO$  - 0,41;  $MgO$  - 0,46;  $S$  - 0,82;  $P$  - 0,01;  $C_{ТВ}$  - 88,02; древесный уголь:  $Fe_{общ}$  - 0,58;  $FeO$  - не обнаружен;  $Fe_2O_3$  - 0,83;  $SiO_2$  - 0,10;  $Al_2O_3$  - 0,05;  $CaO$  - 0,73;  $MgO$  - 0,29;  $S$  - 0,02;  $P$  - 0,09;  $C_{ТВ}$  - 79,85 и карбонизат рексил:  $Fe_{общ}$  - 0,28;  $FeO$  - не обнаружен;  $Fe_2O_3$  - 0,40;  $SiO_2$  - 1,56;  $Al_2O_3$  - 1,04;  $CaO$  - 0,27;  $MgO$  - 0,32;  $S$  - 0,34;  $P$  - 0,02;  $C_{ТВ}$  - 94,84. Расчёт исходных шихтовых материалов провели по методике, предложенной Юсфиним Ю.С. и Пашковым Н.Ф. Показано, что шихта для приготовления исходных рудо-угольных окатышей должна состоять из 83,78 % концентрата ССГПО и 16,22 % доменного кокса; 82,39 % концентрата ССГПО и 17,61 % древесного угля; 84,78 % концентрата ССГПО и 15,22 % карбонизата рексила. Методом ДТА определены температуры начала взаимодействия магнетитового концентрата ССГПО с восстановителями. Установлено, что активное восстановление оксидов железа твердым углеродом начинается при температурах: для древесного угля – 780 °С, карбонизата рексила – 840 °С, доменного кокса – 930 °С. При проведении металлзации рудо-угольных окатышей (в качестве связующего жидкое стекло,  $\rho = 1,20 \text{ г/см}^3$ ) в печи Таммана установлено, что наиболее предпочтительным является использование в качестве восстановителя карбонизата рексила, полученные металлизованные окатыши содержали 55 – 60 %  $Fe_{мет}$ , степень металлзации составила 83-90 %.

**Ключевые слова:** концентрат ССГПО, углеродсодержащие восстановители, доменный кокс, древесный уголь, карбонизат рексил, рудо-угольные окатыши

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## **EFFECT of SOME CONDITIONS of CHARGE PREPARATION on ZINC DISTILLATION from OXIDIZED ORE**

**Abstract:** Production experience shows that use of many types of secondary mineral resources is technically feasible and efficient. One of the resource in the production of non-ferrous metals is use of waste of iron and steel industry, in which the content of non-ferrous metals up to industrial conditions. Thus, in dusts of gas purification of some plants of ferrous metallurgy the zinc content reaches 15 %. The results of the study of the binder agent effect during the briquetting of charge, the type of the carbonaceous reducing agent, the consumption of reducing agent, fineness of charge components on the process of carbothermal reduction of zinc from oxidized zinc ore with the addition of stale dust of gas cleaning of blast furnace smelting were presented. Bentonite, hydrated lime and treacle were tested as binding agent for briquetting of charge. It is established that optimum binding agent is treacle in an amount of 4.5-5.0 % by weight of the weight of the ore. It is shown that the residual zinc content in a product of the reduction roasting when using the special coke obtained from coal of Shubarkol deposit is 1.9 times less, than at using anthracite and 3.3 times less, than at using metallurgical coke, i.e. special coke is the most active reducing agent. The carbon consumption during carbothermal reduction of zinc from oxide ore with the addition of dust is 22-24 % lower than in case of zinc recovery from ore. It was found that crushing of charge to class +0.071-0.04 microns reduces the degree of zinc sublimation. If the size of charge is +1.0 microns, the residual zinc content in the cinder is increased. High recovery efficiency is achieved with the following composition of charge, wt. %: oxidized zinc ore – 53.8; dust of gas purification of blast furnace smelting – 26.9; special coke – 21.0; treacle – 5.3.

**Key words:** zinc, charge, oxidized zinc ore, gas purification dust of blast furnace smelting, binding agent, carbothermic reduction

**Introduction.** The annual volume of world production of zinc exceeds 10 million tones. Half of this volume is used to protect steel against rust. Environmentally attractive fact in favor of use of zinc is that 80 % of it is used again, and it does not lose its physical and chemical properties. Protecting steel against corrosion, zinc helps to preserve natural resources, such as iron ore and energy. Extending the service life of steel, zinc increases the life cycle of goods and

capital investments, i.e. buildings, bridges, power and water distribution, telecommunications, thus protecting investment and helping to reduce repair and maintenance costs [1].

It is known [2], that 85 % of the total world production of zinc is obtained from concentrates, and the rest of sub-standard and secondary raw materials and wastes of chemical and metallurgical industries.