# Agglomeration Technology of Fine Manganese Concentrates with the Application of Granulation

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Abstract: The technology for processing the HIMS concentrate, including its partial regrinding and drying, mixing, granulating and agglomeration in a high layer, has been developed. A technological scheme for the reconstruction of the Bogdanovskaya sinter plant of the JSC "Pokrovskiy GZK" was developed. Studies have shown that it is impossible to obtain strong, non-destructible (in the process of transportation) and handling granules from this concentrate due to an insufficient amount (6-8 %) of fine particles with a particle size of -0,056 mm, which mainly affect the lumpiness of raw materials. A new technology for the preparation and agglomeration of fine concentrates, including preliminary granulation was developed.

## 1 INTRODUCTION AND ANALYSIS OF PREVIOUS STUDIES

The introduction of deeper and more advanced enrichment schemes is one of the ways to increase the manganese extraction during the manganese ores enrichments in Ukraine in the situation of a constant decline of the original ore qualities. It includes both flotation and high-intensity magnetic separation (HIMS) (Wu, 2015). As a result, it causes an increase in the amount of fine particles and moisture in the concentrates.

Deposits of manganese ores on the globe are distributed very unevenly, just as uneven their material composition, which is associated with the genesis of ores (Kuleshov, 2011). A distinctive feature of manganese ores from domestic deposits is the relatively low manganese content and high concentration of phosphorus and silica (Kutsin, 2012), which does not allow, unlike most foreign ores, to use raw materials without prior enrichment and storage.

A large number of works (You, 1999; Kwon, 2021; DeFerreira, 2021) are devoted to the study of the manganese minerals recoverabilities, ores and concentrates, while the work (DeFerreira, 2021) is devoted to the study of Brazilian ores. However, the data available in the literature are often ambiguous. It is known that MnO2 and MnCO3 dissociate at relatively low temperatures – 510 and 176 °C, respectively.

In (Kutsin, 2012; Yuanbo, 2017; Singh, 2020) the issues of mineralogical research of manganese ores of sedimentary genesis are considered, the issues of mineralogy and physicochemical properties of manganese component of iron-manganese modules are studied, as well as the method of thermochemical determination of manganite in manganese ores and the recommendation for Nikopol basin. In the article (Kulik, 1996) the research of modern tendencies of development of the manganese mining industry of the world and Ukraine is executed, the ways of increase of competitiveness of the domestic enterprises on

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increase of competitiveness of the domestic enterprises on extraction of manganese ore depending on a modern market situation are offered. The authors of (Kulik, 1996) made an important conclusion that the sources of relatively high-quality ores for manganese and related components are man-made deposits (sludge storages), the development of which can be one of the most promising areas, which will also solve current environmental problems.

In (Samal, 2021; Eom, 2016) the characteristics of the mineral components of oxidative and carbonate manganese ores are given. It is determined that the nature of transformations during heat treatment (agglomeration, firing of pellets and briquettes, preheating) is largely determined by chemical, mineralogical and particle size distribution, as well as other properties of raw ore.

For the adequacy of raw material evaluation, it is necessary to compare the quality indicators of manganese concentrates produced in Ukraine and abroad (Table 1).

Table 1: Technical requirements for the quality of manganese ores and concentrates for smelting ferroalloys

| Component | Mass fraction, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | For pheromarganese* | | | | For silicomanganese * | | | |
| | Ukraine I grade | Western Europe I grade | Western Europe II grade | USA grade «A» | Ukraine II grade | Western Europe I grade | Western Europe II grade | USA grade «B» |
| Mn, no less | 43,0 | 48,0 | 46,0 | 46,0 | 34,0 | 44,0 | 40,0 | 40,0 |
| Fe, no more | - | - | 7,5 | 8,0 | - | 9,0 | 12,0 | 16,0 |
| $SiO_2$, no more | - | 7,0 | 9,0 | 12,0 | - | 10,0 | 12,0 | 15,0 |
| P, no more | - | 0,12 | 0,15 | 0,18 | - | 0,15 | 0,15 | 0,30 |

*the requirements to Nikopol oxide concentrates and ores and concentrates of foreign producers are specified

Table 2: Chemical composition of the studied samples of manganese ores

| № | Producing country | Mass fraction of components, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mn | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Fe_2O_3$ | $P_2O_5$ | $Na_2O$ | $K_2O$ | Losses during calcination |
| 1 | Georgia | 47,20 | 12,09 | 1,88 | 1,92 | 0,75 | 1,86 | 0,47 | 0,21 | 0,59 | 3,29 |
| 2 | Brazil | 47,60 | 9,30 | 1,20 | 1,03 | 1,34 | 9,30 | 0,14 | 0,23 | 1,15 | 2,29 |
| 3 | Australia | 47,00 | 13,05 | 1,63 | 2,67 | 0,98 | 8,94 | 0,07 | 0,12 | 0,03 | 3,88 |
| 4 | Ghana-I | 30,00 | 14,05 | 2,65 | 4,65 | 5,08 | 1,72 | 0,16 | 0,28 | 0,24 | 31,6 |
| 5 | Ghana-II | 39,79 | 19,30 | 4,20 | 0,40 | 0,12 | 7,10 | 0,32 | 0,19 | 0,63 | 5,02 |
| 6 | Ghana-III | 30,50 | 13,52 | 2,20 | 4,81 | 4,85 | 1,05 | 0,25 | 0,24 | 0,21 | 32,6 |

Table 3: The results of studies of the general physical properties of manganese ores

| № | Producing country | Mass fraction of moisture, % | Density, $kg/m^3$ | | | Total porosity, % | Strength (DSTU 3200-95) on impact on fraction more than 5 mm, % |
|---|---|---|---|---|---|---|---|
| | | | bulk | imaginary | true | | |
| 1 | Georgia | 4,0 | 1740 | 2400 | 3880 | 38,14 | 31,0 |
| 2 | Brazil | 8,4 | 2940 | 4210 | 4270 | 10,92 | 58,0 |
| 3 | Australia | 2,8 | 2110 | 3850 | 4020 | 4,23 | 75,6 |
| 4 | Ghana-I* | 1,6 | 2300 | 3240 | 3270 | 1,4 | 71,0 |
| 5 | Ghana-II | 7,2 | 2090 | - | 3670 | - | - |
| 6 | Ghana-III | 1,6 | 2120 | 3190 | 3370 | 5,3 | 72,0 |

* manganese ore Ghana I and III - carbonate, Ghana II - oxide.

Table 4: Mineralogical composition of the studied samples of manganese ores

| № | Producing country | Distribution of manganese by mineral phases, % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ore phase | | Pyrolusite | | Minerals of the psilomelan group | | Brownite | | Manganite | | Manganese carbonates (rhodochrosite, calcium rhodochrosite) | |
| | | Mn | M | Mn | M | Mn | M | Mn | M | Mn | M | Mn | M |
| 1 | Georgia | 47,20 | 76,4 | 43,7 | 69,1 | - | - | - | - | 3,2 | 6,1 | 0,3 | 1,2 |
| 2 | Brazil | 47,60 | 78,6 | 16,3 | 25,8 | 14,6 | 25,3 | 16,7 | 27,5 | - | - | - | - |
| 3 | Australia | 47,00 | 77,2 | 2,5 | 3,9 | 3,2 | 5,4 | 40,5 | 66,0 | - | - | 0,8 | 1,9 |
| 4 | Ghana-I | 30,00 | 78,5 | 1,1 | 1,7 | - | - | 1,2 | 1,9 | - | - | 27,7 | 74,9 |
| 5 | Ghana-II | 39,7 | 66,2 | 18,3 | 29,0 | 17,0 | 29,4 | 3,8 | 6,0 | - | - | 0,6 | 1,8 |
| 6 | Ghana-III | 30,5 | 77,8 | - | - | - | - | - | - | - | - | 30,5 | 77,8 |

M – the amount of manganese mineral in the ore part of the sample, %.

Samples of manganese ores of different chemical and fractional compositions (Tables 2, 3, 4), which are currently widely used in the production of manganese ferroalloys at domestic enterprises, were studied. These include samples of manganese ores from deposits in Georgia, Brazil and Ghana (Grishenko, 2015).

Analyzing the studies results of the manganese ores physical properties, given in table. 3, it should be noted that the ores have low porosity, except for ores from Georgia, and a higher actual density compared to domestic manganese concentrates. Mechanical strength (fraction more than 5 mm) of lump manganese ores is low and inferior in strength to manganese agglomerate made from domestic concentrates. For fluxed and non-fluxed manganese agglomerates of domestic production, the mechanical strength is 76-80 % and the porosity is 8-22 %.

## 2 METHODOLOGY, PURPOSE AND OBJECTIVES OF THE STUDY

Analytical, laboratory and industrial methods were used as research methods. A comparison of quality indicators of manganese concentrates produced in Ukraine and abroad was performed. Chemical and mineralogical composition studies of the of dust and sludge of JSC "Nikopol Ferroalloy Plant" was conducted in the laboratory. The study of the agglomeration process was carried out at the experimental production facilities in the Mechanobrchormet Institute.

Difficulties with the production of competitive manganese alloys on domestic raw materials have intensified in recent years, when, on the one hand, domestic enterprises began to increase production of low-phosphorus grades of silicomanganese and ferromanganese, and on the other hand, increasing energy costs acted before. This required the use of imported manganese ores at Ukrainian ferroalloy plants. Thus, the problem of complex studies of physical and chemical properties and metallurgical value of manganese raw materials with their subsequent aggregation has become extremely relevant for Ukrainian metallurgists.

The objectives of the article are to perform comprehensive studies of physicochemical properties and metallurgical value of manganese raw materials of various deposits used in the production of ferroalloys in high-capacity ore reduction furnaces, to consider returning to the production of enrichment products lumping is not possible. It is also necessary to compare the requirements for the quality of manganese ores and concentrates according to the regulations of different countries.

## 3 RESULTS OF THE STUDY

Manganese concentrates sintering with increased moisture capacity (12.0-26.5 %) and low bulk density (1350-1750 kg/m$^3$) results in high losses on ignition (up to 10.5-25.5 %). To compare with the iron ores agglomeration, there is a significant shrinkage of the layer, and the specific yield of sintering products is 1.5-2.0 times lower.

Since the sintering of such raw materials requires an increased mass fraction in the return charge as well as coke breeze (by 1.5-2.0 times), an increase in the proportion of thin and moisture-consuming concentrates in the sinter charge makes the sintering process even more difficult due to a decrease in the gas permeability of the charge.

Foreign specialists at their sinter plants don’t have any experience in sintering manganese charges that include thin concentrates with high moisture capacity either. Thin concentrates in various quantities are added to gravity concentrates at domestic manganese sintering plants. Such materials are supplied to the sinter mixture in an unprepared form.

Laboratory and industrial studies have established that the introduction of an unprepared HIMS concentrate into the sinter charge in an amount of more than 15% reduces the technological parameters of the agglomeration process.

The urgency of the problem is confirmed by the fact that the production volumes from thin concentrates at the Pokrovskiy Ore Mining and Processing Plant (JSC "Pokrovskiy GZK") will increase to 300 thousand tons per year. The existing capacities of the sinter plant will not be able to process such a quantity.

The «Mekhanobrchermet Institute» specialists with specialists from «State University of Economics and Technology» and «Igor Sikorsky Kyiv Polytechnic Institute» have developed a new technology for the preparation and agglomeration of fine concentrates, including preliminary granulation.

During the research manganese concentrates of the current production of Pokrovskiy Ore Mining and Processing Plant were used. Chemical and granulometric composition of materials, as well as their physical properties are presented in the table 5 and 6.

Table 5: Chemical composition of manganese concentrates from JSC "Pokrovskiy GZK"

| Concentrate | Mass fraction of components, % | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mn | $SiO_2$, | $A1_2O_3$ | CaO | MgO | $Fe_2O_3$ | $Na_2O$ | $K_2O$ | $P_2O_5$ | $CO_2$ | passing breeds |
| Oxide, gravity | 36.30 | 22.68 | 1.98 | 2.12 | 1.18 | 3.40 | 0.60 | 1.20 | 0.40 | 1.94 | 0.20 |
| Carbonate, gravity | 28.00 | 14.75 | 4.08 | 8.38 | 1.70 | 3.85 | 0.62 | 1.40 | 0.47 | 19.56 | 25.50 |
| HIMS | 31.70 | 26.80 | 2.10 | 3.4 | 1.20 | 3.70 | 0.58 | 1.34 | 0.378 | 2.14 | 13.10 |

Table 6: Granulometric composition and physical properties of concentrates from JSC "Pokrovskiy GZK"

| Material | Mass fraction, %, size classes, mm | | | | | | | | | Moisture content, % | Specific surface area, $m^2/kg$ | True density, $kg/m^3$ | Bulk density, $kg/m^3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | + 10 | 10-5 | 5-3 | 3-1 | 1-0.5 | 0.5-0.25 | 0.25-0.16 | 0.16-0.1 | 0.1-0 | | | | |
| Oxide gravity concentrate | 22.0 | 13.3 | 7.0 | 30.9 | 6.8 | 9.8 | 10.2 | – | – | 17.5-22.5 | – | 3430 | 1600-1700 |
| Carbonate Gravity concentrate | 14.7 | 21.9 | 57.4 | 6.3 | – | – | – | – | – | 12.0-19.0 | – | 3230 | 1650-1750 |
| Concentrate HIMS | – | – | – | – | 23.8 | 11.7 | 10.6 | 23.6 | 24.1 | 6.2-21.5 | 88.0-98.0 | 3600 | 1350-1450 |

Gravitational oxide and carbonate concentrates are mainly represented by a fraction of 1-10 mm. The HIMS concentrate has a particle size of -1.0 mm and a moisture content of 24-26 %. Studies have shown that it is impossible to obtain strong, non-destructible (in the process of transportation) and handling granules from this concentrate due to an insufficient amount (6-8 %) of fine particles with a particle size of -0.056 mm, which mainly affect the lumpiness of raw materials. It is possible to increase the proportion of fine particles by grinding a part of the HIMS concentrate in dry grinding mills with simultaneous drying.

The refinement of the grinding technology was carried out on a plant operating in a closed cycle with an air-pass separator and equipped with a gas burner. A batch of crushed product with a mass fraction of a fraction of -0.056 mm equal to 70-75 % and a specific surface area of 265-280 $m^2/kg$ was obtained at the installation in the spent mode in order to conduct research on its pelletizing into granules with a particle size of 2-8 mm. Such granules absolutely meet the requirements of the sintering process.

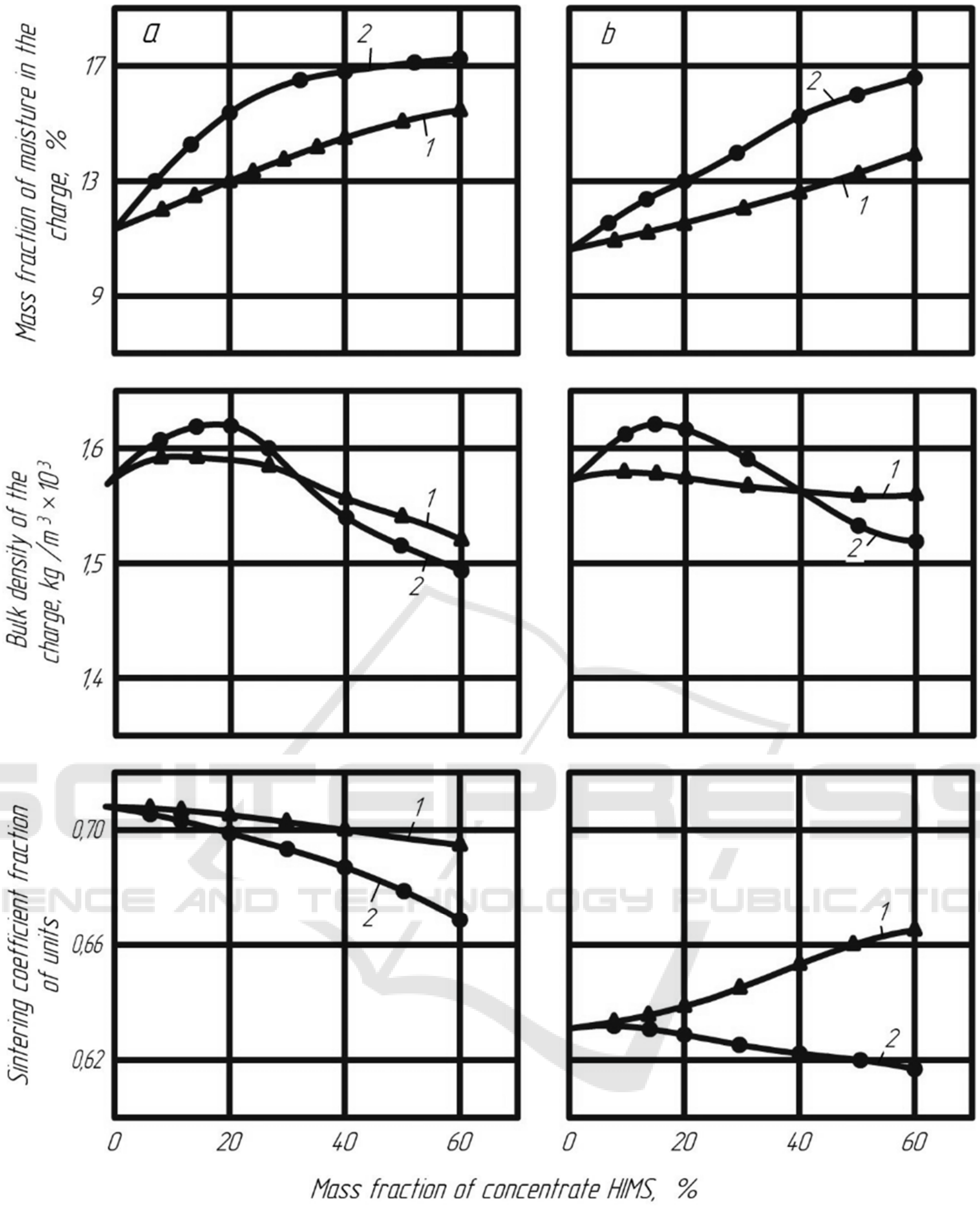


Figure 1: Dependence of the physical properties of the sinter charge and the sintering coefficient on the mass fraction of the HIMS concentrate in the ore part of the charge during sintering of the agglomerate with oxide grade II (a) and carbonate (b) gravity concentrates: 1 - concentrate of HIMS in the form of microgranules; 2 - HIMS concentrate in its original form

The crushed material in various amounts was dosed to the original HIMS concentrate, mixed and pelletized in a bowl pelletizer with the addition of water. Strength tests of granules were carried out in order to determine their resistance to destruction during overloading and mixing with larger and more abrasive components that make up the sinter charge, as well as during intermediate storage in a hopper under conditions close to industrial ones. The research results are shown in the table 7.

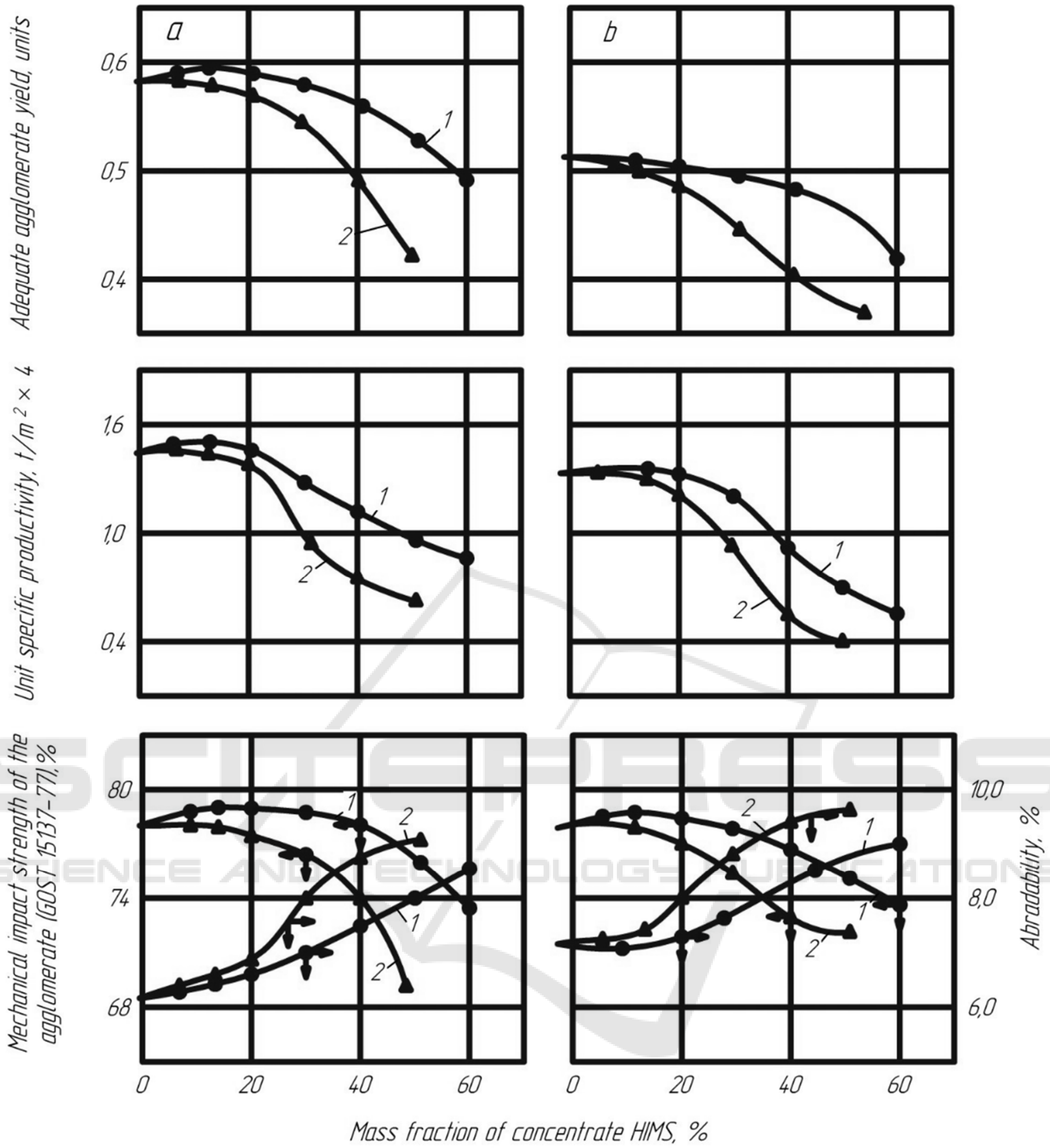


Figure 2: Dependence of the technological parameters and the strength of the agglomerate on the mass fraction of the HIMS concentrate in the ore part of the charge during sintering of the agglomerate with oxide grade II (a) and carbonate (b) gravity concentrates:
1 - HIMS concentrate in the form of microgranules;
2 - HIMS concentrate in its original form.

The dependence of the physical properties of the sinter charge and the sintering coefficient in the production of manganese agglomerate on the mass fraction of the HIMS concentrate in the initial and prepared form is shown in Fig. 1. The dependence of the technological parameters of the agglomeration process on the mass fraction of the HIMS concentrate is shown in Fig. 2.

An increase in the mass fraction of the HIMS concentrate over 15-20 % leads to a deterioration in the physical and gas-dynamic properties of the sinter charge, which in turn reduces the technological parameters of sintering and the quality of the sinter. When the mass fraction of the HIMS concentrate in an unprepared form in the sinter batch is equal to 40-60%, the agglomeration process becomes unfeasible.

Due to the lower moisture capacity of the carbonate gravity concentrate, the larger average particle size and their greater roughness in comparison with the oxide gravity concentrate of the II grade, the effect of the addition of the HIMS concentrate to the charge has a lesser effect on the deterioration of technological parameters. When sintering carbonate concentrate with additives of HIMS concentrate, due to the high mass fraction of volatiles, the yield of suitable agglomerate decreases and the rate of filtration of exhaust gases. In combination with thermal destruction of lump carbonate concentrate, this causes to a significant increase in dust removal in the process of sintering.

Table 7: Characteristics of the properties of the initial charge from the HIMS concentrate and granules obtained from it

| Indicator | Experiment options | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Moisture mass fraction in the HIMS concentrate before mixing, %: | | | | | |
| in the original | 16.0 | 16.0 | 25.0 | 25.0 | 25.0 |
| in shredded | – | 3.0 | 3.0 | 3.0 | 3.0 |
| Mass fraction in the charge, %: | | | | | |
| HIMS concentrate | 100 | 80 | 60 | 40 | 20 |
| crushed HIMS concentrate | – | 20 | 40 | 60 | 80 |
| Mass fraction -0,056 mm in the charge, % | 6.2 | 25.9 | 37.3 | 48.7 | 60.1 |
| Bulk density of granules. | 1330 | 1350 | 1390 | 1430 | 1510 |
| Mechanical strength of granules, after dropping twice from a height of 2 m onto a metal plate (fraction yield +2 mm), % | 32.4 | 68.7 | 86.8 | 96.9 | 96.4 |

When using HIMS concentrate in the sinter charge in the form of granules, the characteristics of the sintered layer are improved. Due to the increase in the gas permeability of the charge, it is possible to carry out the sintering process in a higher layer with an unlimited amount of the proportion of granules in the ore part of the sinter charge. With this technology, rolling of solid fuel into granules is eliminated, which reduces the specific consumption of coke breeze.

It has been established that the addition of HIMS concentrate to the sinter charge in an unprepared form in an amount of 15 to 30 % and of 30 to 50 % reduces the specific productivity of the sinter plant by 25 and 50 % respectively, as well as the strength of the sinter and increases the loss of the initial material.

The results of sintering class II oxide gravity concentrate with the addition of HIMS concentrate in the form of granules were processed on a computer using the program of multiple correlation-regression analysis. A mathematical model of the agglomeration process has been created, which is described by the regression equations connecting the output parameters with the controlled ones:

$$Q = 2.7288 + 0.0471\tau + 0.000799SV - 0.018642G - 0.014B - 0.15201C;$$

$$P = 77.4465 + 1.06765\tau - 0.0019413SV - 0.079485G - 0.0033346B + 0.21690C,$$

where Q - unit specific productivity, $t/(m^2 \cdot h)$; $\tau$ - ignition time, min; SV - sintering vacuum, Pa; G - mass fraction of granules of the HIMS concentrate (in relation to the oxide gravitational concentrate of the II class), %; B - mass fraction of return in the charge, %; C - mass fraction of coke breeze in the charge, %; P - agglomerate impact strength, %.

The obtained regression equations were used to optimize the sintering process. The optimization problem consisted in determining such values of $\tau$, SV, G, B and C within the specified limits, at which the specific productivity of the installation and the mechanical strength of the agglomerate reached the maximum values.

The conditions and results of optimization of the sintering process are given in table 8.

The second method of pre-coating of fine concentrates was investigated - the method of briquetting, the feature of which was the absence of binder and increasing the pressing pressure to 30 MPa. A batch of briquettes was obtained to conduct research on sintering the sinter using a sinter batch of raw briquettes measuring 15×15×20 mm. Experiments on agglomeration have shown that with a content of 30-40 % of briquettes in the charge, the height of the sintered layer can be increased to 700-900 mm.

In the process of processing the sludge formed during the enrichment of oxidized manganese ores on high-intensity magnetic separators, a concentrate with a high specific surface area and high moisture content was obtained. Concentrate of high-intensity magnetic separation of manganese sludge contains, %: 33,0 Mn; 24.8 $SiO_2$; 2.9 $Al_2O_3$; 6.2 FeO; 0.435 $P_2O_5$ and other components. The true density of the concentrate is 3420 kg/m$^3$, the specific surface area is 250 m$^2$/kg; bulk density 1500 kg/m$^3$, angle of natural slope 43.5 degrees.

Table 8: Conditions and results of optimization of the sintering process

| Parameters | Parameter type | Symbol | Restrictions | | Optimal value |
|---|---|---|---|---|---|
| | | | Bottom line | Upper bounds | |
| Specific productivity, t/(m$^2$·h) | Output | Q | 0.9 | 1.6 | 1.33 |
| Agglomerate impact strength | | P | 74.0 | 81.0 | 79.2 |
| Ignition time, min. | Adjustable | τ | 3.0 | 5.5 | 5.0 |
| Vacuum, Pa | | SV | 5000 | 11000 | 6500 |
| Mass fraction of granules, % | | G | 25.0 | 60.0 | 30.0 |
| Mass fraction of return, % | | B | 15.0 | 35.0 | 20.0 |
| Mass fraction of fines, % | | C | 7.0 | 9.5 | 9.0 |

The concentrate is characterized by high moisture content - the moisture content in it after filtration is 30-40 %. The concentrate was pelleted in bowl pelletizers with a diameter of 1 and 2 m to obtain raw pellets of uniform particle size distribution (diameter 14-18 mm) without the use of reinforcing additives, and then subjected to heat treatment. The optimal parameters of heat treatment of pellets are given in table. 9.

Table 9: Optimal parameters of heat treatment of pellets

| Technological modes | Duration of heat treatment, min | Temperature of the heat carrier, °C | | Filtration speed, m$^3$/(m$^2$·s) | Lquefaction, ×10$^3$ Pa |
|---|---|---|---|---|---|
| | | At the entrance | At the exit | | |
| Heating the top of the layer | 90-120 | 200 | 30-40 | 0,3-0,5 | 2,00 |
| Blow drying from below | 12 | 350 | 80-90 | 1,2-1,4 | 5,00 |
| Blow drying on top | 3-4 | 350 | 80-90 | 1,1-1,2 | 5,00 |
| Heating | 6-7 | 700-900 | 200-350 | 1,1 | 5,00 |
| Burning | 12-15 | 1150-1180 | 400-500 | 0,9-1,0 | 5,00 |
| Recuperation | 3 | 1000 | 500 | 0,9 | 5,00 |
| Cooling | 15-16 | 20-25 | 800-300 | 1,3-1,4 | 5,00 |

The introduction of 1.0-1.2 % of finely ground solid fuel into the charge intensifies the firing process, reduces the temperature interval between the horizons of the fired layer, and increases the specific productivity of the installation. The main average quality indicators of pellets are as follows:

| | compressive strength, kN/pellet | impact strength (fr. +5 mm), % | specific productivity, t/(m$^2$·h) |
|---|---|---|---|
| without solid fuel | 1,7 | 90 | 0,57 |
| with the addition of 1% anthracite: | 1,27 | 87 | 0,72 |

# 4 CONCLUSIONS

1. One of the ways to increase the rate of manganese extraction in the enrichment of manganese ores in Ukraine in a constantly declining quality of source ore is the introduction of deeper and more advanced enrichment schemes, including flotation and high-intensity magnetic separation (HIMS), although this leads to increased fine particles and moisture in concentrates.

2. A comparative analysis of chemical, mineralogical compositions and physical characteristics of imported and domestic manganese ores and concentrates, as well as the laws of transformation of the phase composition in the process of regenerative heat treatment. It is confirmed that the main distinguishing feature of the studied manganese raw materials from foreign producers is the low value of the modulus of phosphorus ($P/Mn < 0.0035$) and silica ($SiO_2/Mn$ from 0.5 and below), which allows to achieve high technical and economic performance.

3. On the basis of the studies performed, it was established that with the introduction of 30-50 % of the HIMS concentrate into the sinter batch, the productivity of the sinter plant decreases by 25-50 %, the strength indicators of the agglomerate deteriorate, and the removal of dust increases.

4. The technology for processing the HIMS concentrate has been developed, including its partial regrinding and drying, mixing, granulating and agglomeration in a high layer. The optimal parameters of agglomeration have been determined, which make it possible to carry out the process without reducing the technological parameters when using 30-45 % HIMS concentrate in the sinter batch.

5. A technological scheme was developed for the reconstruction of the Bogdanovskaya sinter plant of the JSC "Pokrovskiy GZK". The technical and economic assessment of the developed technology that was carried out indicates its high efficiency.

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