The development of fine manganese concentrate lumping technology at PJSC Nikopol Ferroalloy Plant

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ABSTRACT

The particle and chemical compositions of fine manganese concentrate produced from sludge at Ordzhonikidze Mining and Processing Enterprise have been presented. The technology of manganese sinter agglomeration from manganese ore and concentrates deployed at PJSC Nikopol Ferroalloy Plant has been analyzed. The necessity of preliminary lumping of fine manganese concentrate before sintering stage has been shown. It has been proposed to use peat-hydroxide reagent as binder for lumping of fine manganese concentrate. The qualitative characteristics of peat-hydroxide reagent have been provided. The industrial tests have been carried out and efficient ratio of sinter charge components has been determined. The developed technology has been introduced in the industrial scale.

1. INTRODUCTION

The intensification of production, sustainable use of material and power resources, environmental protection based on low- and non-waste operational schedules are the key trends for further development of ferrous metallurgy, in particular, of one of its power intensive sectors – ferroalloy industry [1-3].

A lot of sludge was generated during the industrial operation of Nikopol manganese ore deposits, when producing marketable manganese concentrates as manganese raw materials beneficiation by-product. In particular, sludge balance reserves exceed 130 million tons at Ordzhonikidze Mining and Processing Enterprise (OMPE). OMPE sludge contains 8-15% of manganese, 0.15-0.25% of phosphorus, 25-30% of silica, 1.5-4% of calcium and magnesium oxide respectively and 2-4% of ferrum. At the moment, process flowchart of dump sludge beneficiation using high-intensity magnetic separation with production of fine oxide-grain manganese concentrate has been developed at OMPE. The qualitative characteristics of fine oxide-grain manganese concentrate are presented in Tables 1.1 and 1.2.

Table 1.1 Chemical composition of oxide-grain concentrate, % wt

No.	Mn	SiO_2	CaO	MgO	Al_2O_3	Fe	P	LOI	W
1	33.3	26.2	2.2	2.0	2.1	4.5	0.17	12.7	22.1

Table 1.2 Particle composition of oxide-grain concentrate, % wt

No.	0-0.063 mm	0.063-0.1 mm	0.1-0.4 mm	0.4-1.0 mm	> 1.0 mm
1	1.9	44.0	23.4	26.8	3.9

Manganese concentrate produced from sludge dump is very fine (fraction is 0-1 mm) and cannot be effectively used as charge component for ferroalloys melting without preliminary lumping.

2. EXPERIMENT

The manganese raw materials fines are lumped using agglomeration method at PJSC Nikopol Ferroalloy Plant. The sinter machines of type AKM-5-105 with sintering area of 115 m^2, working surface length of 42 m, working surface width of 2.5 m and sinter strand movement speed of 1.5-6.0 m/min are used for the above mentioned process. The wetted manganese ores and concentrates are used as sinter charge components, coke and anthracite are used as fuel and limestone is used as fluxing addition. The technological parameters of manganese raw materials agglomeration process at PJSC Nikopol Ferroalloy Plant are presented in Table 2.1.

The charge ignition at the temperature of about 1200°C is the initial stage of manganese raw materials agglomeration process. High temperature (1200-1400°C) is achieved as a result of fuel carbon combustion and intensive air supply in the combustion area. During the heating, ore and concentrate grains are dehydrated and then softened with partial formation of liquid phases. In such a case, chemical transformations of compounds included in them, including partial reduction of manganese oxide, occur. The sinter charge is partially and fully melted; subsequently, if the air is continued to be supplied, it is quickly cooled down and crystallized to produce porous pitch. The temperature of baked sinter after fuel combustion completion is 800-900°C. Further, it is subjected to the forced cooling at conveyor-type continuous sinter machine. The cooled sinter is directly delivered with conveyer system to the proportioning bunkers of ore smelting furnaces.

Table 2.1 Main agglomeration process parameters

No.	Parameters	Values
1	Carbon content in sinter charge, %	6.3-6.5
2	Charge layer height on strand, mm:	
3	- before compaction	370-400
4	- after compaction	340-365
5	Sinter charge compaction level, %	8-9
6	Ignition hearth temperature, °C	1150-1250
7	Negative pressure in front of exhauster, kPa	9-10
8	Temperature in front of exhauster, °C	75-90
9	Working speed of sinter strand movement, m/min	1.6-3.2
10	Content of 0-5 mm fines in sinter, %	7.3-7.6
11	Returns output during agglomeration, %	25-35

The quality of manganese sinter is significantly defined by its chemical composition and mineralogical features of charge components. At PJSC Nikopol Ferroalloy Plant, manganese sinter baked from oxide and carbonate concentrates of Nikopol deposits, carbonate ores imported from Ghana, South Africa, Brazil and Gabon used in various ratios in the sinter charge are deployed for ferrosilicon manganese melting. The chemical composition of source manganese raw materials for sintering and sinter composition are provided in Table 2.2.

Table 2.2 Chemical composition of source manganese raw materials and sinter at PJSC Nikopol Ferroalloy Plant

No.	Type of raw materials	Chemical composition, % wt							
		Mn	SiO_2	CaO	MgO	Al_2O_3	Fe	P	LOI
1	oxide concentrate, 1 grade	44-47	10-12	1.5-3	1-2	1-2	1.5-2	0.17-0.2	11-13
2	oxide concentrate, 2 grade	35-38	20-22	2-4	1.5-2	1.5-2	1.5-2	0.17-0.2	12-15
3	carbonate concentrate	27-29	15-19	8-11	1.5-2	1.5-2	1.5-2	0.19-0.23	23-28
4	carbonate concentrate, Ghana	27-30	13-15	5-7	5-7	2-2.5	0.8-1.2	0.06-0,09	28-30
5	manganese concentrate	37-40	20-24	7-10	2-6	2-3	2-4	0.08-0.19	0-3

In general, the following phases are present in manganese sinter composition: tephroite ($2MnO \cdot SiO_2$), hausmannite (Mn_3O_4), jacobsite ($MnFe_2O_4$), dicalcium silicate ($2\ CaO \cdot SiO_2$), solid solutions (CaO- MnO_x- MgO) and vitreous phase [4-5].

3. RESULTS AND DISCUSSIONS

The sintering process parameters and strength characteristics of sinter are largely defined by gas-dynamic resistance of charge layer, which depends on homogeneity, size distribution, fuel and moisture distribution uniformity through the entire layer volume. Gas dynamics of agglomeration process, detailed in the paper [6], is generally described by the equation:

$\Delta p = h\rho w(k_1\upsilon + k_2 w)$ (3.1),

where: Δp is gas pressure loss, h is sinter charge layer height, ρ is gas density, w is gas filtration speed, υ is gas kinematic viscosity, k_1 and k_2 are gas-dynamic resistance coefficients.

The particle size distribution of materials providing for optimal technological parameters of sintering process and gas-dynamic resistance of sinter charge at PJSC Nikopol Ferroalloy Plant is as follows: manganese concentrates are 3-10 mm, sinter fuel is 1-5 mm and flux is 1-3 mm.

At the initial stage of fine concentrate (0-1 mm) lumping technology development, the attempts of its direct use in the charge composition for baking of manganese sinter instead of oxide concentrate (2 grade) portion were undertaken. The industrial tests demonstrated that addition of fine manganese concentrate in quantity of more than 5% in the sinter composition results in dramatic reduction in sinter machine capacity and sinter strength characteristics (Fig.1). The deterioration of agglomeration process and sinter quality was caused by the sharp increase in gas-dynamic charge resistance.

Based on the experiments, it was concluded that particle composition of fine manganese concentrate eliminates the possibility of its efficient lumping using agglomeration process without preliminary preparation by lumping method. The issue was solved in collaboration with National Metallurgical Academy of Ukraine (NMetAU) through the use of peat-hydroxide reagent as binder (Table 3.1) for achievement of the required charge size distribution.

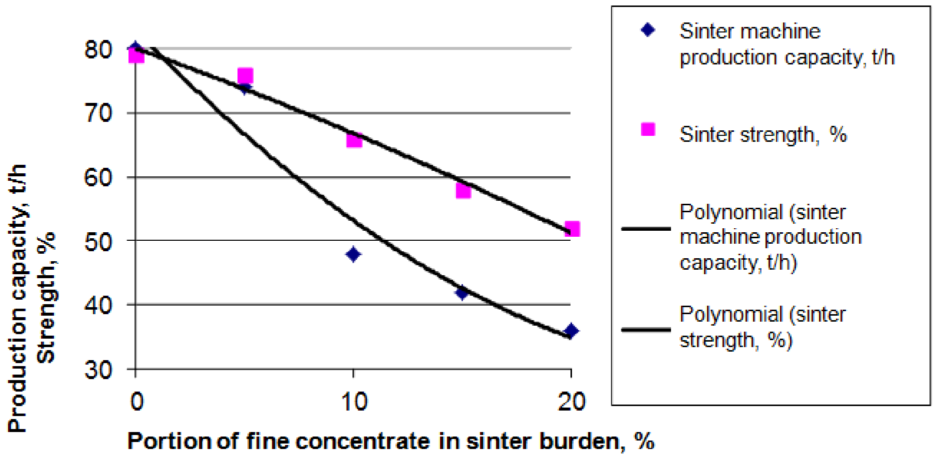

Figure 3.1: Variation of sinter machine production capacity and sinter strength depending on portion of fine concentrate in sinter charge

The peat-hydroxide reagent is produced by processing of black peat with NaOH aqueous solution and refers to lignin-alkaline reagents. It represents dry fine material containing more than 30% of humic acid sodium salts. It is used as binder in sinter- and iron-making. It is produced as powder or cylindrical granules with diameter of 8-10 mm and length of 10-50 mm.

The fine manganese concentrate was lumped by its mixing with peat-hydroxide reagent in the ratio of 5.5:1 (by weight) at the warehouse of sinter shop with further formation of granules with dimensions of 1-4 mm in the nodulizing drum before charge charging onto sinter machine. During the industrial tests, the technology of manganese sinter baking for ferrosilicon manganese melting using lump fine concentrate was developed. The charge composition was calculated with regard for production of manganese sinter with Mn content at the level of 39%.

Table 3.1 Technical requirements for peat-hydroxide reagent

No.	Parameters	UOM	Normal value
1	Particle composition:		
2	- fraction of more than 3 mm in powder, max.	%	7
3	- fraction of less than 8 mm in granules, max.	%	7
4	pH	units	7.5-10.5

5	Ash mass fraction	%	15-25
6	Soluble humate content	%	5-14

When conducting investigations, the sinter charge containing 50-80% of fine concentrate was baked, the weighed portions of Mn-containing materials (oxide concentrate of 1 grade and carbonate concentrate) were calculated based on the achievement of standard manganese content in the manganese sinter. The baking was carried out, when sinter charge layer height was 340-350 mm, speed was 1.6-2.4 m/min and ignition temperature was 1000-1200°C. The carbon content in sinter charge was 6-6.3%. The appearance of sinter cake was characterized by apparent combustion area in front of grate with the height up to 1/5 of cake; no combustion sources were observed on sinter cake bend. The sinter machine production capacity was 66 t/h, returns output was within the range of 30-35%, sinter strength was 76-76.5%. Variation of agglomeration process parameters depending on portion of fine concentrate in sinter charge is presented in Figures 3.2-3.3.

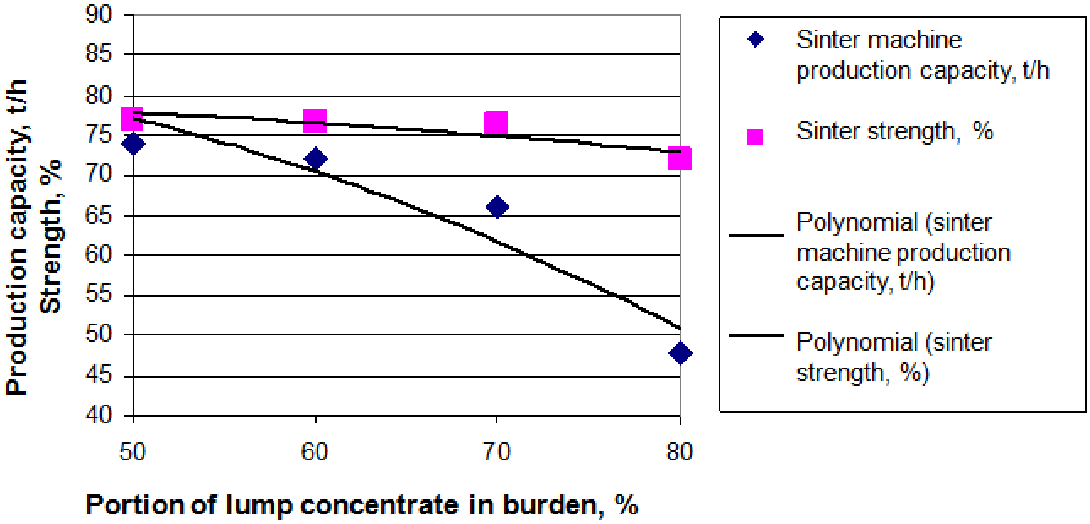

Figure 3.2: Variation of sinter machine production capacity and sinter strength depending on portion of lump concentrate in sinter charge

The optimal parameters of agglomeration process, as shown in Figures 2-3, remain unchanged, if the portion of lump concentrate in charge composition is 50-70%.

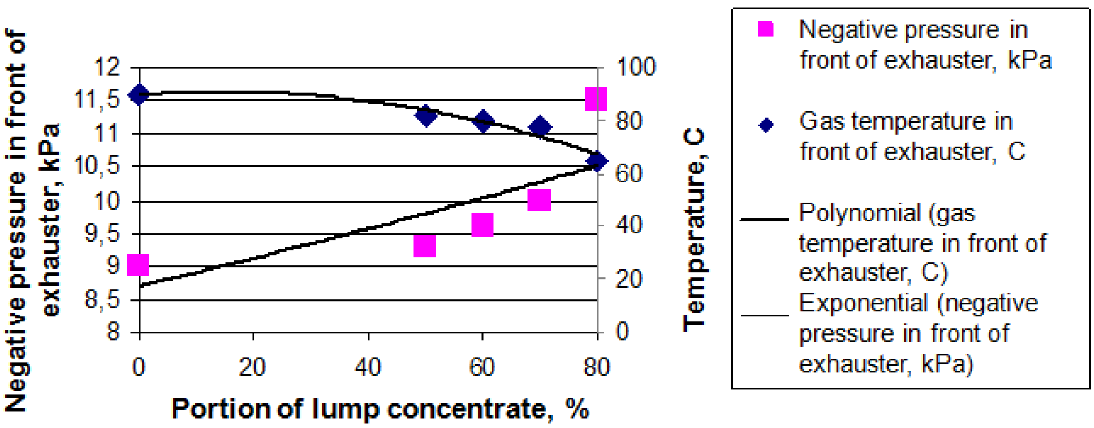

Figure 3.3: Change in gas-dynamic properties of sinter charge

SUMMARY

The performed studies allowed developing reasonably efficient technology of fine manganese concentrate (fraction is 0-1 mm) lumping that makes it possible to produce standard manganese sinter with the required strength characteristics for ferrosilicon manganese melting, whereas the optimal productivity of the existing process equipment at sinter shop of PJSC Nikopol Ferroalloy Plant is preserved. The developed and introduced technology allows using manganese raw materials from man-made sources in the production and mitigating environmental pollution.

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