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ISSN 0543-5846
METABK 62(1) 135-138 (2023)
UDC – UDK 669.74-66.082:669.051:66.099:620.17:539.26=111

PREPARATION OF PELLETS FROM MANGANESE CONCENTRATE FOR THE PRODUCTION OF FERROMANGANESE

Received – Primljeno: 2022-03-17
Accepted – Prihvaćeno: 2022-07-15
Preliminary Note – Prethodno priopćenje

The results of studies on the production of pellets for the metallurgical stage based on manganese concentrate with a manganese content of 34 %, obtained from waste manganese-containing sludge, are presented. Kaolin and high-iron diatomite in combination with calcium oxide and coke were tested as binder components of charges. Manganese-containing pellets were produced by composition pelletizing in a Eirich high-speed mixer-granulator. The size of pellets in the form of rounded granules was in the range of 5 - 10 mm. Sintering roasting temperature of pellets was 1 150 - 1 200 °C. Strength of roasted pellets was 1 313 with kaolin as binder, 1 940 with diatomite, and diatomite with lime addition – 2058 N/pellet respectively.

Keywords: manganese concentrate, pellets, granulation, strength, x-ray research

INTRODUCTION

Global consumption of manganese grows due to the increase in steel production. Manganese is used mainly in the form of ferroalloys (high-carbon and refined ferromanganese, ferrosilicomanganese, etc.) in ferrous metallurgy [1-3]. Natural manganese ores are used to prepare metallic manganese and ferroalloys.

A huge amount of small fractions of raw materials are formed during processing of manganese ore (extraction, crushing, beneficiation, transportation), not suitable for use in metallurgical processes. Waste is accumulated in dumps, sumps, warehouses, occupying huge areas, causing problems of economic and environmental nature. To involve in the production of finely divided manganese concentrates obtained by enrichment of waste sludge, it is necessary to create an effective technology for their agglomeration [4].

Three pelletizing methods are used in metallurgical practice: briquetting, sintering and pellet production [5-7].

Pellet production is a relatively new, the most effective and rapidly developing direction of pelletizing ore materials.

Strengthened pellets have good recoverability, sufficient strength, homogeneity in grain size. Besides fuel consumption for pellet roasting is half as much as for sintering, and harmful emissions with the waste gases are significantly reduced or even eliminated [8].

The presented work is devoted to obtaining pellets from beneficiated manganese-containing sludges, which will reduce the amount of waste of beneficiation plants, improve the environmental situation and create additional products for the production of ferromanganese.

MATERIALS AND METHODS

Compositions containing concentrate obtained by beneficiation of manganese sludges, binders (kaolin or diatomite), fluxing additive CaO and reducing agent-coke were the object of the study.

Pellets were obtained by pelletizing the raw mixture of a given composition in a Eirich laboratory mixer-granulator.

X-ray diffractometer (XRD) D8 Advance (BRUKER) was used for the X-ray analysis of the initial raw materials and synthesized compositions, α-Cu.

Microscopic studies of roasted pellets were performed on a LEICA DM 250 microscope in reflected light, a JEOL scanning electron microscope. Strength of samples was determined on the MIP – 25 test press.

The concentrate obtained by the beneficiation of waste manganese sludge, with a particle size of less than 5 mm, was the main component of the charge for pellet production. Kaolin and high-iron diatomite were used as binder components. Chemical compositions of the initial materials are shown in Table 1.

The main raw materials contain the following minerals according to the X-ray phase analysis of the samples, i.e. brownite $Mn_7O_8(SiO_4)$, hausmannite (Mn_3O_4), hematite ($Fe_{1,984}O_3$) that are metallic ones, and magnesian calcite ($(Mg_{0,03}Ca_{0,97})(CO_3)$), acermanite ($Ca_2Mg(Si_2O_7)$) and quartz ($SiO_2$) – non-metallic ones.

Diatomite as a binder in the production of pellets for the metallurgical industry is little studied. According to the content of aluminum and silicon oxides, it can be classified as a clayey raw material, semi-acidic in na-

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Table 1 **Chemical composition of the initial materials**

Content of oxides/ mass. %	Components		
	Manganese concentrate	Diatomite	Kaolin
MnO	44,14	-	-
SiO_2	8,72	8,80	44,21
Al_2O_3	1,29	4,52	29,02
Fe_2O_3	18,01	50,12	2,17
CaO	17,40	8,06	0,83
MgO	0,62	9,67	1,14
Na_2O	0,16	0,49	1,11
K_2O	0,13	3,15	0,18
others	2,59	3,69	6,41
products after calcination	6,94	11,5	14,93

ture, according to the content of coloring ($Fe_2O_{3\,+}$ TiO_2) – to raw materials with high dye content.

Diatomite is represented by quartz, jarosite, albite, microcline, and muscovite. Mineral composition of kaolin: kaolinite - the main mineral, boehmite, diaspore, ferruginous chlorite, chamosite, ussingite silicate $Na_2[AlSiO_3]OH$ – impurity.

The roasted limestone (calcium oxide) was the fluxing component, the coke was the reducing agent.

RESULTS AND DISCUSSION

Sample cylinders with 16 mm in diameter were made by pressing at a specific pressure of 10 MPa to study the dependence of strength properties of manganese-containing pellets on the type of the binder component and to determine the optimum roasting temperature of the compositions.

Samples were dried in natural conditions within 1 day, then at temperature 110 - 115 °C to a residual moisture of not more than 3,0 mass. %. The roasting was performed in a program-controlled electric furnace in the interval 1 000 - 1 200 °C at a given temperature for 1 hour.

3 compositions based on a manganese concentrate with the proportions of components specified in Table 2 were tested in the work.

The test results of the roasted samples (Table 2) showed that their compressive strength increases with increasing roasting temperature. However, samples using kaolin as a binder in the amount of 10 %, at a temperature of 1 200 °C showed melting signs. That is, the temperature interval of sintering of such a composition is in the range above 1 150 and below 1 200 °C.

The sintering roasting temperature can be considered 1 200 °C for samples based on the concentrate with 10 % high-iron diatomite added. The strength of the samples was 58,5 N/mm^2. Samples roasted at 1 150 °C had signs of under – roasting.

When an additional fluxing component (calcium oxide) is introduced into the charge, the strength of the roasted samples slightly decreased. Obviously, a greater number of fusible phases are formed in the structure of such a composition during the roasting, and when they are cooled they form the glass phase that reduces the strength properties of the samples.

Table 2 **Compositions and strength of samples after roasting**

Composition of compositions/ mass. %	Strength of samples on compression, N/mm^2 at t roasting/°C		
	1 100	1 150	1 200
Mn-concentrate - 87, kaolin - 10, coke – 3.	43,0	23,0	-
Mn-concentrate - 87, diatomite - 10, coke – 3.	-	24,2	58,5
Mn-concentrate - 82, diatomite - 10, CaO - 5, coke - 3.	-	15,3	42,4

Charges were prepared based on manganese concentrate and pellets were produced (Table 2). Pellets were obtained by pelletizing in a Eirich laboratory mixer-granulator.

The pelletizing process was performed at steel drum rotation speed of 170 rpm, swirler rotation – 3000 rpm, drum inclination angle – 30 °, rotation of the drum – counterclockwise. These granulation parameters were established based on previously acquired experience in research in this direction [9-10]. A 1,5 % aqueous solution of carboxymethylcellulose was used as a temporary binder.

The granulated material was dried in natural conditions for a day, then at a temperature of 110 - 300 °C for 40 - 60 minutes until the residual moisture does not exceed 3,0 mass. %. Compositions and properties of manganese-containing pellets are given in Table 3.

Table 3 **Charge compositions and strength of manganese-containing pellets**

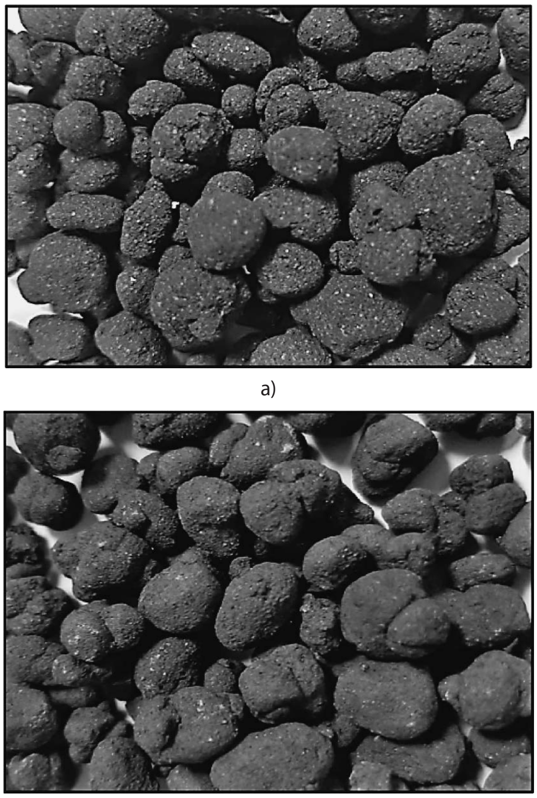
Property values	Charge compositions		
	Mn-concentrate - 87 %, kaolin - 10 %, coke - 3 %	Mn-concentrate - 87, diatomite -10 %, coke - 3 %	Mn-concen-trate - 82 %, diatomite - 10 %, CaO - 5 %, coke - 3 %
t roasting/ °C	1 150	1 200	1 180
compres-sive strength, N/ pellet	1 313	1 940	2 058
Content of oxides/mass. %			
Mn_{total}	38,40	38,40	36,19
Fe_2O_3	15,92	20,70	19,77
CaO	15,21	15,93	19,27
SiO_2	12,00	8,47	8,03

Pellets were roasted in the interval 1 150 – 1 200 °C (respectively: 1 – 1 150, 2 – 1 200, 3 – 1 180 °C).

Full-scale pellet samples based on manganese concentrate are shown in Figure 1.

The phase composition of the obtained manganese pellets wad determined by X-ray phase and microscopic methods of study of roasting products (Table 4).

The X-ray phase analysis results for roasted manganese-containing pellets showed that when kaolin is used



a)

b)

Figure 1 Full-scale samples of manganese pellets: a) on kaolin bond, b) from diatomite in combination with CaO

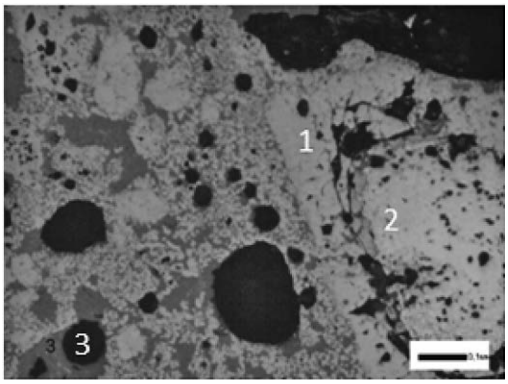
as a binder the following phases are formed in the product structure: jacobsite, Ulvöespinel, ferrian and ferrous boustamite.

Ulvöespinel, ferrian belong to the spinel phase of complex composition. When high-iron diatomite and lime are put together, the content of jacobsite in the structure increases up to 84,4 %. Only two phases are formed: an oxidized form of manganese-iron compound jacobsite and complex hedenbergite.

Table 4 **Phase composition of roasted manganese-containing pellets**

Phases	The formula	S-Q/ %
Composition 1: Mn-concentrate - 87 %, kaolin - 10 %, coke - 3 %		
Jacobsite	$MnFe_2O_4$	77,5
Ulvöespinel, ferrian	$Fe(Fe_{1,387}Ti_{0,585}Al_{0,028})O_4$	16,6
Ferrobustamite	$Ca(Mn^{+2},Fe)Si_2O_6$	5,9
Composition 2: Mn-concentrate - 87 %, diatomite - 10 %, coke - 3 %		
Jacobsite	$MnFe_2O_4$	77,9
Hedenbergite, aluminian	$Ca(Fe_{0,821}Al_{0,179})$ x $(SiAl_{0,822}Fe_{0,178}O_6)$	14,5
Bustamite, calcian	$Ca(Mn^{+2},Ca)Si_2O_6$	7,6
Composition 3: Mn-concentrate - 82 %, diatomite - 10 %, CaO - 5 %, coke - 3 %		
Jacobsite	$MnFe_2O_4$	84,4
Hedenbergite, aluminian	$Ca(Fe_{0,821}Al_{0,179})$ x $(SiAl_{0,822}Fe_{0,178}O_6)$	15,6

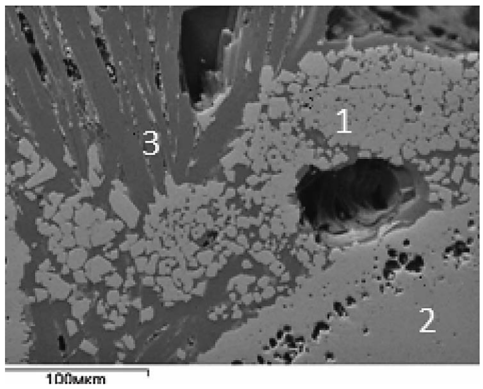
The structure and phase composition of manganese-containing pellets were also studied using optical and electron microscopes. Examination of the polished (anshlif) microscope in reflected light at a magnification of 100 showed the presence of the main phase - jacobsite (Figure 2, point 1). Besides, phases - manganese oxide (Figure 3, point 2) and silicates - (Figure 3, point 3) were established.



1 - jacobsite, 2 - manganese oxide, 3 - complex manganese silicate

Figure 2 Microstructure of pellet composition 3 with reflected light, and magnification 100

The microstructure of annealed manganese-containing pellet studied using scanning electron microscope (SEM) is shown in Figure 3, the chemical composition of points in thin sections - in Table 5.



x 240

1 - jacobsite, 2 - manganese oxide, 3 - complex manganese silicate

Figure 3 Microstructure of manganese pellets (SEM)

Table 5 **Content of oxides in the studied points**

Content of oxides/mass. %	Spectrum No.		
	1	2	3
MgO	-	0,62	1,68
Al_2O_3	3,80	2,31	0,23
SiO_2	-	2,65	46,54
CaO	-	1,00	18,21
TiO_2	-	0,13	-
MnO	96,20	71,78	33,33
FeO	-	21,51	-
Total	100,00	100,00	100,00

CONCLUSION

Manganese-containing pellets for metallurgical processing were obtained based on manganese concentrate with a manganese content of 34 %, obtained from waste manganese-containing sludge. Kaolin and high-iron diatomite were used as binding components.

Compressive strength of annealed pellets of composition – concentrate with kaolin was 1 313, concentrate with high-iron diatomite – 1 940 - 2 058 N/pellet.

The phase composition of the roasted pellets is mainly represented by the manganese mineral jacobsite in the amount of 77 - 84 %, bustamite – 6 - 8 % and hedenbergite of complex composition – 14 -15 %.

Acknowledgments. The work is performed with financial support from Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (grant AP09258880).

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Note: The responsible for English language is A. Kurash, Almaty, Kazakhstan.