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EFFECT OF THE AMOUNT OF COKE CONSUMPTION ON THE SINTERING PROCESS OF EL-BAHARIA IRON ORE

Summary. The amount of coke breeze is one important parameter affecting on the sintering process and in the quality of the produce sinter. In this work the effect of coke breeze consumbtion on the sintering process of El-Baharia iron ore deposite was studied. The main results of this work is as follows:

a - The increase of amount of coke breeze improves the amount of ready made sinter

b - The productivity of sintering machine and the produuctivity at blast furnace yard reached to maximum value at 7% coke breeze.

WPŁYW ILOŚCI ZUŻYWANEGO KOKSIKU NA PRZEBIEG PROCESU SPIEKANIA RUDY EL-BAHARIA

Streszczenie. W pracy przedstawiono wyniki badań zmiany podstawowych parametrów procesu i jakości spieku o zasadowości $CaO/SiO_2 \approx 1,14$, z rud o uziarnieniu poniżej 8mm, z dodatkiem koksiku od 4 do 8%, co 1%. Określono wydajność procesu, wytrzymałość i redukcyjność spieku oraz przewidywano wydajność procesu wielkopiecowego, w którym zużywany byłby wytworzony spiek.

1. Introduction

Many authors [1-3] have found that the optimum fuel content for sintering of hematite, proceeding with high efficiency is acquired only together with 4-5% coke. Higher values lead to increase in the FeO and Fe contents.

Mohamed [4], observed that decreasing the coke by 1% (from 5 to 4%) is accompanied by a 10% increase of the fines produced from the shatter test , decrease of amount of ready sinters by 18% and decrease of metallic Fe and FeO by 9%.

Scotford , et al [5], Mikka, et al [6] , Vegman [7] , Karabasof et al [8] and Shalabi [9], found that the strength of sinter was increased with the increase of fuel in the raw mix.

Danoly et al [10] found that the strength of the sinter was decreased with the increase of coke in the raw mix, up to a certain value of fuel, above which the strength was increased.

Mikka, et al [6], Karabasof ,et al [8] , Shalabi [9], Danloy, et al [10], and Abd El-Khalik [11], indicated that the increase of fuel in the raw mix leads to an increase in the percentages of ready made sinter and FeO content in the produced sinter.

Danloy [10] found that the rate of sintering and reducibility were decreased with the increase in the amount of fuel in the raw mix, while El - Tawil [12], found that the sintering rate was decreased with the increase of the fuel in the mix.

Scotfor [5] indicated that the productivity was increased with the increase of fuel in the mix, but Mikka [6] observed that the productivity was increased with increasing the amount of fuel in the raw mix up to certain value, above which the productivity was decreased.

Karabasof [8] found that the productivity was decreased with increasing the percentage of fuel in the mix.

Shalabi et al [13] found that increasing the rate of the coke breeze in the raw mix improves the amount of ready made sinter and its strength, increases the percentage of FeO, decreases the reducibility, the sulphur content and increases the softening temperature of the sinter. But increasing the rate of coke breeze decreases the vertical velocity, hence decreases the productivity of the sinter.

Dhup and Sakar [14] pointed that their is an optimum amount of coke to produce better sinter. The lower coke amount prevents reaching the correct sintering temperature, with consequent drop in the amount of sinter product and in its strength. High coke in the charge tends to give high bed temperature, which causes more liquid phase and lower bed permeability, and hence, a lower quantity of sinter.

The aim of tgis work is studied the effect of amount of coke breeze consumption on thhe sintering of El-Baharia iron ore and the quality of the produced sinter

2. Experimental work

2.1. Materials

The raw materials used in the sintering process are El-Baharia Oasis iron ore (El-Gedida iron ore deposits), limestone, recycled sinter and coke breeze (-2.36, +1.16 mm).

The chemical composition and the particle size distribution of the raw materials are given in Table 1 and Table 2.

2.2. Sintering Apparatus and Sintering Procedure

Sintering experiments were conducted in a laboratory down draft sinter pot, (3kg). Air flow was provided by two fans in series which were capable of producing suction pressure in exess of 11.76 KPa. The temperature of the waste gas which gives an indication of the end of the sintering process was measured by Pt-Pt.Rh. thermocouple. The raw materials were blended together and the required amount of water (9%) was added thorough conduction of mixing to give a good

Table 1

Chemical composition of the raw materials

Coke breeze	Limestone	Iron ore	Component
2.24	-----	52.76	Fe_{total}
-----	-----	-----	Fe_{metal}
3.203	-----	75.37	Fe_2O_3
4.55	1.4	7.58	SiO_2
2.20	0.76	1.97	Al_2O_3
0.732	53.21	0.51	CaO
0.082	0.24	1.46	MgO
-----	-----	3.42	MnO_2
0.022	0.07	0.39	P_2O_5
0.04	0.074	0.326	Na_2O
0.106	0.027	0.154	K_2O
-----	0.1	0.4	Cl^-
-----	-----	1.3	BaO
-----	-----	0.08	Zn
1.08	0.04	0.65	S
-----	42.2	-----	CO_2
1.23	-----	7.56	L. I
88.39	-----	-----	F. C
-----	-----	-----	TiO_2

Table 2

Size analysis of the raw materials

Limestone	Iron ore	Screen size, mm
------	-----	+ 11.20
------	1.67 %	+ 8.00
------	4.69 %	+ 6.68
------	17.21 %	+ 4.00
------	7.69 %	+ 3.327
3.10	9.18 %	+ 2.36
11.10	7.22 %	+ 1.65
10.70	5.21 %	+ 1.168
24.80	12.60 %	+ 0.50
15.00	10.75 %	+ 0.295
19.00	11.28 %	+ 0.125
16.30	12.50 %	- 0.125

permeable green charge. A sinter bed of 0.5 Kg sinter (+10mm) was placed over the grate of the pot to protect it against the high temperature during the sintering operation.The green mix was loaded over the sinter bed layer (hearth layer) in the sinter pot.

The green mix was ignited with a gas flame over a period of 3 minutes. The ignition was done under suction pressure of 5.88 KPa, while the sintering process was done under suction pressure of 11.76 KPa. The sintering time was determined by the time elapsed from the start of igintion until the exhaust gas temperature reached a maximum value [11,15-17]. At the end of the sintering experiment the sinter cake was dropped from the sinter pot on to a steel plate laid on concrete.

The productivity of the sintering machine was calculated according to the following relation. [15].

$$P = 14.4\ V.\ K.\rho$$

where:

P = Productivity of sintering machine (+7mm), ton/(m^2 day),

V = Vertical velocity of sintering machine, (V= H /T) m/min,

H= height of the charge, m,

T= time of sintering, min,

K= Percentage of ready made sinter from the charge, (+7mm),

ρ = bulk density, ton/m^3.

2.3. Strength of sinter (Shatter Test)

The sinter cake was screened over a sieve of +10 mm[15,18], then the sinter of + 10 mm was taken and dropped four times from a height of 2 m. Then out sinter after shatter tester was screened over a sieve of 7 mm. The sinter strength (W) was calculated as the percentage of (-7 mm) sinter relative to +10 mm [11, 19].

$$\text{Sinter Strength (W) \%} = M_1 \times 100 / M_2$$

where: M_1 = weight of sinter of -7 mm after shatter test, kg,

M_2 = weight of sinter of + 10 mm before shatter test, kg.

Notes. When (W) is high value this means the strength of sinter is low, while when (W) is low value, this means the strength of sinter is high.

2.4. Productivity at Blast Furnace Yard

The productivity at blast furnace yard was calculated according to the following relation [11]:

$$P_{B.F} = P \times (100 - W) / 100$$

where:

$P_{B.F}$ = Productivity at blast furnace yard, ton/ (m^2.day),

P = Productivity of sintering machine, ton/(m^2.day),

W = Shatter index (-7 mm),%.

2.5. Reducibility of sinter product

The reducibility of sinter product was carried out in static bed in hydrogen atmosphere 1.5 l/min.) at 800 °C

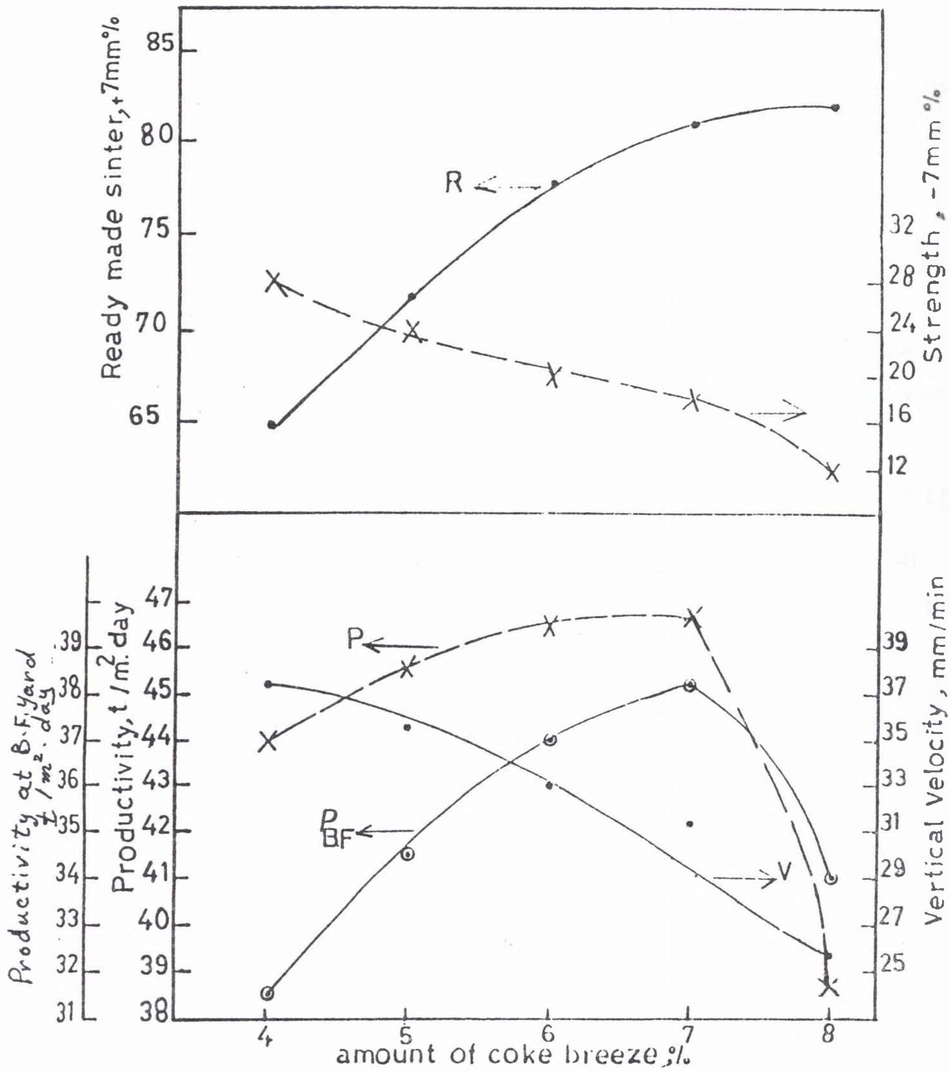


Fig.1. Effect of the amount of coke breeze on some technical properties of the produced sinter
Rys.1. Wpływ dodatku koksiku na własności spieku i wydajność procesu

3. Results and discussion

3.a. Effect of varying amount of coke breeze on some technical properties of iron ore sinter

Fig. 1 shows that as the amount of coke breeze in the raw mix increased from 4% to 8% the percentage of ready made sinter increased from ~ 65% up to ~ 82.5% and the strength of the produced sinter increased from 72% to 88% respectively. This is due to the fact that the increase of coke breeze leads to an increase in the amount of heat evolved during the sintering process and subsequently increase the amount of melt and minerals which have high strength such as magnetite and $CaO.Fe_2O_3$ (magnetite 36.5 Kg / mm^2 and $CaO.Fe_2O_3$ 35 kg / mm^2) [13, 20-23] .

Also from the Fig. 1. It is clear that the vertical velocity decreased with the increase of the amount of coke breeze. This is due to the increase of the amount of melt which decreased the permeability of the sinter cake [13].

The productivity of sintering machine and productivity at B.F yard reached maximum value (46.8 and 38.3 ton/m^2 day respectively) at 7% coke breeze . Beyond 7% coke breeze the productivity of sintering machine and productivity at B.F. Yard decreased . This fact is due to the effect of vertical velocity and sinter strength.

3.b. Effect of Varying Amount of Coke Breeze on The Chemical Composition, Reducibility and Softening Temperature of The Produced Sinter

Table 3 shows the effect of varying amount of coke breeze on the chemical composition of the produced sinter.

Table 3

The chemical composition of the produced sinter

Amount of coke breeze, %	Chemical composition, %						
	Fe_{total}	FeO	Fe_{metal}	SiO_2	CaO	S	Degree of metallization
4	53.8	13.12	0.80	8.30	9.50	0.130	1.50
5	53.8	15.00	1.00	8.40	9.60	0.082	1.86
6	53.6	19.17	1.40	8.50	9.70	0.100	2.60
7	54.4	20.58	1.60	8.55	9.74	.0110	2.94
8	54.4	24.19	2.30	8.52	9.74	0.120	4.22

As the amount of coke breeze increased the amount of FeO, Fe metal and the degree of metallization increased as shown in table 3. This is due to the decomposition and reduction of higher oxides to lower oxides and metal. also due to the increase of carbon monoxide formed on the combustion of fuel in the charge which leads to increase the reduction of higher oxide to lower oxide [24].

The percentage of sulphur in the produced sinter decreased from 0.13to 0.082% as the amount of coke breeze increased from 4% to 5% then increased to 0.12% when the coke breeze increased to 8%. This can be explained by the fact that at 5% coke breeze the temperature in preheating zone and heating zone is high and also there is sufficient amount of free oxygen in the waste gas which facilitated to remove of sulphur from the sinter, while at 4% coke breeze, the amount of heat is not sufficient for desulphurization. At more than 6% coke breeze the amount of free oxygen in the waste gases is not sufficient for the desulphurization [13, 15, 20].

Fig. 2. shows the relationship between the degree of reduction, softening temperature of the sinter and the amount of coke breeze in the raw mix. From which it is clear that the degree of reduction decreased with the increase of amount of coke breeze while the softening temperature increased . This attributed to the increase of FeO content in the produced sinter Table. 3 and also due to the decreased of porosity of the sinter [25-29].

3.c. Petrographic studies

3.c.1. X -Ray Analysis

Samples of the produced sinter with different amount of coke breeze were subjected to x-ray analysis Fig. 3. The differactograms of the studied samples show lines of hematite and magnetite as the main minerals of the sinter. Wustite could be identified in samples and increased with the increase of coke breeze in the raw mix. Secondary hematite decreased with the increase of coke breeze.

3.c.2. Microscopic Studies

Microscopic study Figs. 4, 5, showed the morphology and texture of the produced sinter. Crystalline of magnetite, and hematite and wustite were detected in different textures. Magnetite generally appeared in the different sizes and shapes embedded in silicate matrix. Dendritic magnetite is also observed.

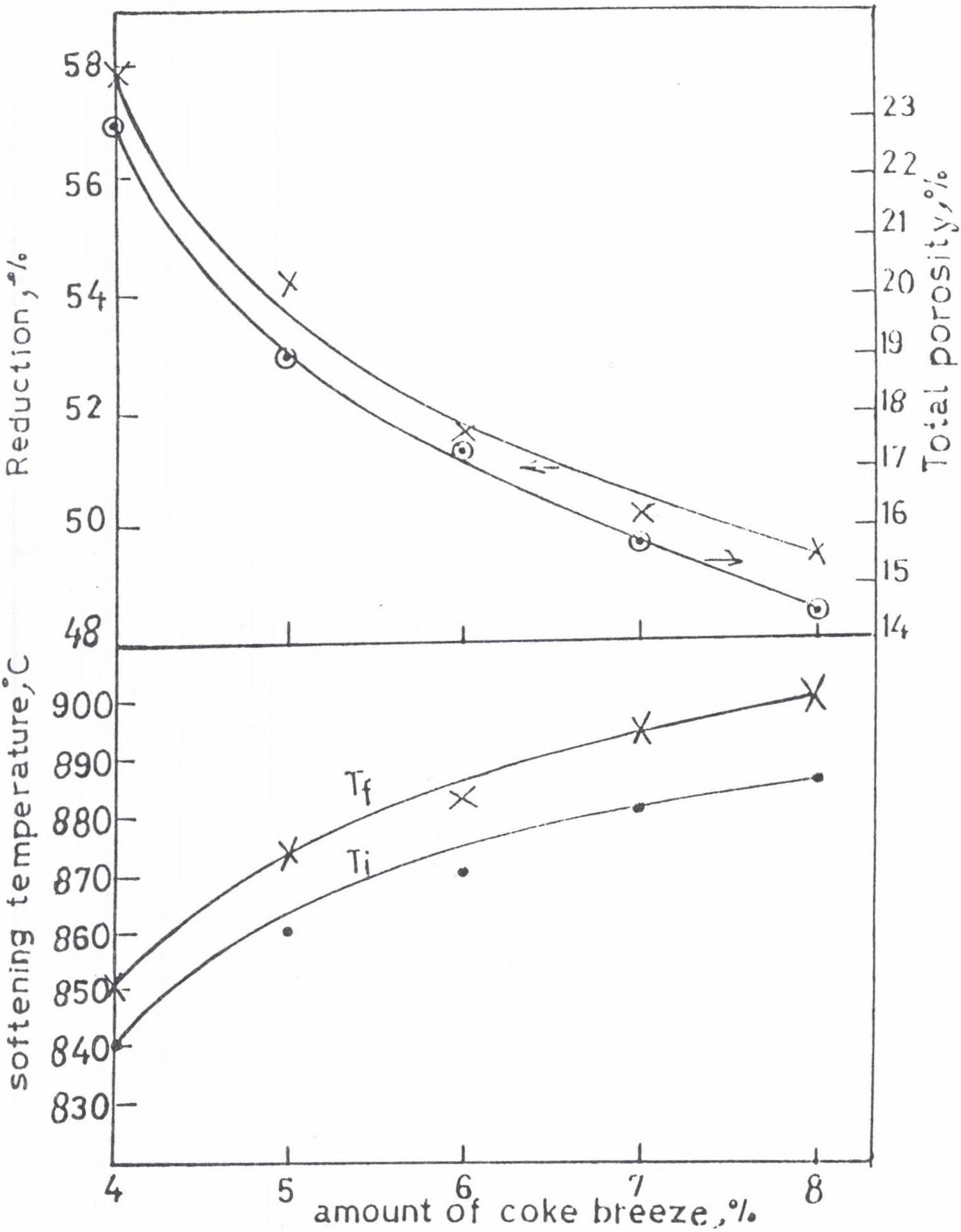


Fig.2. Effect of amount of coke breeze on the reduction %, porosity and softening temperature of the produced sinter

Rys.2. Wpływ dodatku koksiku na stopień redukcji, porowatość i temperaturę mięknięcia produkowanego spieku

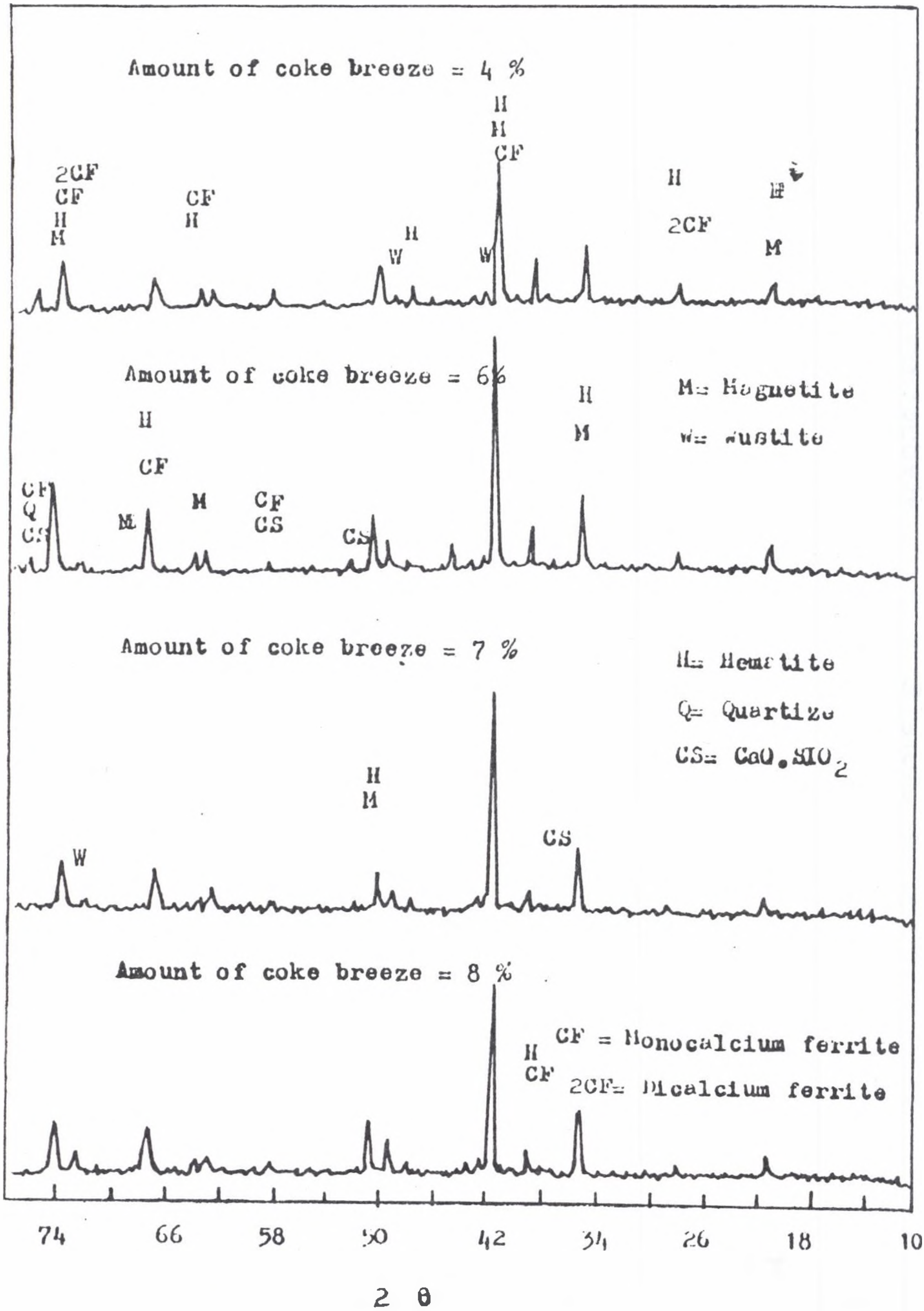
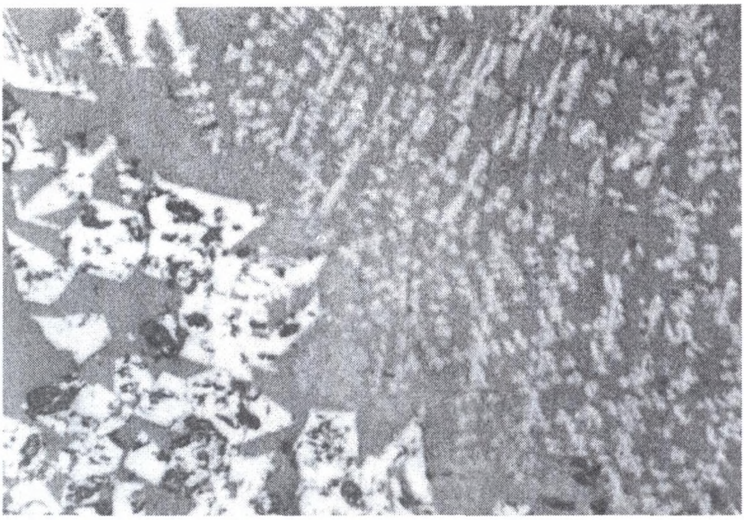
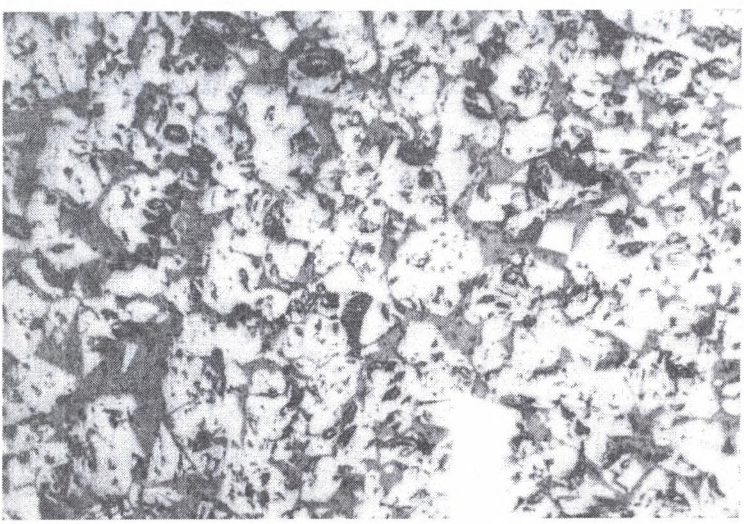


Fig.3. X-Ray diffractograms show the effect of the amount of coke breeze on phases of the sinter products
Rys.3 X-Ray dyfraktogram spieku przy różnym dodatku koksiku



A



B

Fig.4. Microstructure of the produced sinter

A) Dendritie and crystal of magnetite (white) embedded in silicate matrix (4% coke breeze), (X 200)

B) Crystal and globular of magnetic and scondary of hematite embedded in silicate matrix (7% coke breeze), (X 200)

Rys.4. Mikrostruktura spieku

A) Dentryty i kryształy magnetytu (białe) w osnowie krzemianowej (4% dodatku koksiku)

B) Globularne kryształy magnetytu i wtórnego hematytu w osnowie krzemianowej (7% dodatku koksiku)

Fig.5. Microstructure of the produced sinter. Magnetite in different size and shape embedded in silicale matrex (8% coke breeze), (X 200)
Rys.5. Mikrostruktura spieku. Magnetyt o różnej wielkości i kształcie (postaci) zanurzony w osnowie krzemianowej

Conclusion

1. The increase of the rate of coke breeze in the raw mix improves the amount of ready made sinter and its strength. This is due to the fact that the increase of coke breeze leads to the increase in the amount of heat evolved during the sintering process and subsequently increase the amount of melt and minerals which have high strength .
2. The vertical velocity decreased with the increase of the amount of coke breeze. This is due to the increase of the amount of melt which decreased the permeability of the sinter cake .
3. The productivity of sintering machine and productivity at B.F yard reached maximum value at 7% coke breeze.
4. As the amount of coke breeze increased the amount of FeO and Fe metal and the degree of metallization increased.

5. The percentage of sulphur in the produced sinter decreased to minimum value at 5% coke breeze.
6. The degree of reduction was decreased as the amount of coke breeze increased.

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Streszczenie

Zużycie koksiku jest ważnym składnikiem decydującym o przebiegu procesu spiekania i jakości spieku. Badano zmianę podstawowych parametrów procesu i jakości spieku o zasadowości $CaO/SiO_2 \approx$ 1,14, z rud o uziarnieniu poniżej 8 mm, z dodatkiem koksiku od 4 do 8%, co 1%. Określano wydajność procesu, wytrzymałość i redukcyjność spieku oraz przewidywano wydajność procesu wielkopiecowego, w którym zużywany byłby wytworzony spiek.

Ustalono, że w miarę dodatku koksiku rośnie wytrzymałość i uzysk spieku, a obniża się ilość spieku zwrotnego;

- mimo obniżania się pionowej szybkości spiekania w miarę wzrostu ilości koksiku, ale tylko do 7%, rośnie wydajność procesu spiekania i przewidywana wydajność procesu wielkopiecowego. Przekroczenie 7% dodatku koksiku powoduje gwałtowne obniżenie tych wskaźników;
- dodatek koksiku powoduje obniżenie stopnia utlenienia spieku, a tym samym pogorszenie jego redukcyjności. Za optymalny uznano 7% dodatek koksiku.