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THE INFLUENCE OF CARBON IN SYNTER-MIXTURE ON THE MECHANICAL RESISTANCE OF THE PRODUCED SINTER

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ABSTRACT

The ore consolidation process is a thermal process and it happens at the temperatures of the ore melting beginning, allowing the ore grains, additives and fluxes to be connected into a solid piece of sinter. The amount of carbon in the sinter mixture and the FeO content of the produced sinter affect the mechanical resistance of the sinter. Indicators of mechanical resistance of sinter are very important for evaluating the metallurgical value of sinter. How much of the sinter is grounded during transport to the blast furnace and in the furnace depends on the mechanical resistance. The amount of high-dust, the gas permeability of the furnace, and thus the furnace productivity and fuel consumption depends on the amount of fine fractions in the furnace.

INTRODUCTION

In order to efficiently manage the process of iron production, metallurgical preparation of charge and fuel must be performed in advance by improving their physical and chemical characteristics that will ensure uniform horizontal distribution of gas in the mixture column and optimal temperature distribution over the height of the furnace, in order to:

- increase the productivity of the furnace,
- reduce the energy consumption,
- improve the iron quality,
- reduce the production costs, and
- improve working conditions and environmental protection.

Sinter production must be based on modern knowledge and adapted to the requirements set for the assessment of sinter quality in order to achieve the best possible performance indicators of the blast furnace. Metallurgical and economic feasibility and efficiency of the sinter production process largely depends on the manner and degree of preparation of raw materials and fuels used in the process.

In order to maintain a uniform temperature, heat and chemical regime in the blast furnace, which is a prerequisite for achieving high productivity and low costs of iron production, strict conditions for uniformity are set for:

- chemical,
- granulometric composition, and
- sinter strength.

1. THEORETICAL FUNDAMENTALS OF THE SINTERING PROCESS

Fine ore, concentrate, as well as other fine iron-bearing raw materials that are formed during the production and processing of iron and steel (blast furnace dust, BOF and EAF dust, scale), pyrite, etc., cannot be melted directly in blast furnaces and must be previously merged/enlarged.
The process of enlarging iron ores is a thermal process and takes place at the temperatures of the beginning of ore smelting, which enables the connection of ore grains, additives and fluxes into solid sinter in pieces. The sintering process begins from the moment of ignition of the mixture with the products of combustion of gas fuel, whose temperature reaches 1200 ^{0}C to 1400 ^{0}C [1, 2].
After the passage of the sinter belt under the combustion chamber, the further course of the sintering process takes place at the expense of the heat of combustion of solid fuel with oxygen from the intake air. The combustion products of the fine solid fuel in the narrow surface layer are directed downward by the action of under-pressure, preheating the lower layers of the mixture. The displacement of the carbon combustion in the upper layer and the displacement of the preheating of the mixture adjacent to the upper layer results in the gradual displacement of the fuel combustion zone down to the screen of the sintering machine.
The amount of heat released during the combustion of fuel in the mixture is an important factor that affects the rate of combustion and the height of the temperature in the sintering zone. This amount depends on the quality of the fuel, grain size, its calorific value, as well as the amount of fuel in the mixture. The amount of heat released during combustion directly depends on the amount of fuel in the mixture. Optimal fuel consumption guarantees a sinter of good reductivity and satisfactory strength and it is determined experimentally for each mixture and for each type of fuel [2].
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1.1. Fuel combustion in the sintering process

The combustion of fine coke during sintering takes place in a narrow zone. With fuel grain sizes below 3 mm, the thickness of the combustion zone is about 20 mm. If the grain size of the fuel varies from 1 mm to 8 mm, the thickness of the combustion zone ranges from 10 mm to 40 mm.
Due to the lack of oxygen that occurs in the vicinity of combustible particles and due to the short gas retention time in a narrow zone of high temperatures, the combustion of CO to CO_2 is never fully completed. In most cases, there is a lack of oxygen in the combustion zone, although the sintering process takes place with excess air.
The temperature level of the sintering process depends mainly on fuel consumption. Increasing fuel consumption leads to the formation of a larger amount of FeO. The size of the fuel is also

very important. Larger fuel burns more slowly, with increasing size, the degree of reduction of iron oxides increases. Low fuel consumption does not allow reaching the combustion zone above 1378 ºC, which makes thermal dissociation of hematite impossible. Heat deficiency makes it impossible to obtain sinters of sufficient strength from hematite ores. The case is completely different with the sintering of magnetic ores and concentrates. If the fuel consumption is high, then the magnetite is reduced to FeO and metallic iron [1].

1.2. Melting formation and formation of the final sinter structure

The melting process of the sintering mixture takes place exclusively in the solid fuel combustion zone. The crystallization of the melt begins in the upper parts of the solid fuel combustion zone, due to contact with the sucked cold or preheated air, during which the final structure of the sinter is formed. The mineralogical composition and structure of the sinter depend mainly on the basicity of the mixture, the carbon consumption and the thermal regime of the sinter plant.
The thermal conditions of the sintering process depend mainly on fuel consumption. As the fuel consumption in the sinter mixture increases, the oxide reduction and dissociation processes intensify. Magnetite gradually gives way to FeO, and then to metallic iron, where the final mineral composition can be changed in a wide range by regulating the thermal level of the sintering process. Carbon consumption also depends on the quality of the sinter you want to produce.
Low carbon consumption during sintering gives easily reductive but low-strength sinter, and with normal fuel consumption, solid sinter with a sufficient amount of silicate binder is obtained. Increased and very high fuel consumption makes it possible to produce metallized sinter [1].

2. PHYSICAL PROPERTIES OF SINTER

Physical and mechanical properties of sinter from the point of view of metallurgical requirements for the possibility of application in the process of iron production is determined on the basis of:

- Grain size (>20mm and <5mm),
- strength parameters (TI $_{+6,3mm}$ and AI $_{-0,5mm}$)

2.1 Mechanical resistance at normal temperatures

Mechanical resistance indicators are very important for the assessment of the metallurgical value of ores and prepared charge components, sinters. The mechanical resistance determines how much of the sinter is crushed during transport to the furnace and what will be the amount of fine fractions that will come into the furnace. The amount of blast-furnace dust, gas permeability of the charge and thus the productivity of the furnace and fuel consumption will also depend on this.
For the assessment of resistance indicators, the following differ:

- impact resistance,
- drop resistance,
- wear resistance, and
- pressure resistance.

The resistance of raw ores depends on the mineralogical composition, structure and genesis, while in the case of sinters it largely depends on the sintering temperature, i.e. on the FeO content as an indicator of strength [1].

2.2. Resistance to sinter comminution at increased temperatures

In the case of sinter resistance to comminution at elevated temperatures, it is necessary to distinguish between comminutions that take place in a neutral atmosphere - (resistance to decrepitation) and comminutions in a reductive atmosphere - (thermostability). Both properties are important for the behavior of the sinter as well as for its metallurgical grade. The degree of crushing of the charge in the furnace during the descent in the conditions of elevated temperatures and reduction depends on these properties. Decrepitation at elevated temperatures in a neutral or other atmosphere is due to the influence of internal forces and stresses in a piece of sinter, caused by the pressure of CO and H_2O gases in closed pores as well as stresses in the structure due to heating. Increasing the internal pressure above the tensile strength, leads to the collapse of the piece of sinter.
Comminution due to sinter thermal instability occurs due to internal stresses resulting from changes in crystal structure and lattice under the influence of elevated temperature with simultaneous reduction, when Fe oxides from one crystal modification pass into another [5].

2.3. Sinter grain size

Sinter grain size indicators are very important for assessing the metallurgical value and physical readiness of sinters. The grain composition curve completely defines the grain size of the sinter, because it shows the quantitative share of individual grain sizes in the sinter. Based on the grain size curve, the degree of physical preparation of the sinter can be fully assessed [4].
Physical readiness, granulometric composition and interval have a decisive influence on the gas permeability of the material column and on the distribution of gas flow in the blast furnace, and thus on the amount of blown air, the amount of burned coke and thus the productivity of the furnace. By reducing the charge grain size, the relative resistance to gas flow increases, and thus the amount of air in the furnace decreases and the productivity of the furnace decreases. When charging the blast furnace, the sinter fraction below 5 mm is very unfavorable and harmful. Therefore, the final screening of the sinter is done immediately before charging the furnace [6].

3. EXPERIMENTAL PART

The aim of this paper is to investigate the influence of carbon content in the sinter mixture on the granulometric composition and strength of the sinter produced in the company ArcelorMittal Zenica. All tests of the components of the sinter mixture and the produced sinter were performed in the laboratory of ArcelorMittal Zenica. The paper presents daily averages of analyzed parameters based on shift samples from internal reports of ArcelorMittal Zenica. Samples of the sinter mixture and the sinter produced are taken twice in one shift. The composition of the sinter mixture was always approximately constant, only the carbon content in the sinter mixture changed.

3.1. Test results

Table 1 shows the one-day average values of chemical analysis for three sinter mixtures with different carbon content in the sinter mixture.

Table 1: Chemical composition of sinter mixtures in % [3].

Mix.	SiO_2	FeO	Fe_2O_3	CaO	MgO	MnO	Al_2O_3	Fe	S	C	Moist.	CaO/SiO_2
M1	10,20	3,16	59,44	10,39	1,92	2,21	2,10	43,36	0,08	6,11	10,05	1.02
M2	10,49	2,37	57,47	10,91	2,09	1,99	2,07	42,66	0,08	5,13	9,60	1,04
M3	10,18	2,16	57,12	10,89	2,04	2,03	1,90	41,86	0,08	4,77	9,93	1,07

Table 2 shows the one-day average values of chemical analysis of the produced sinter with different carbon content in the sinter mixture.

Table 2: Chemical composition of the produced sinter in % [3].

Sinter	SiO_2	FeO	Fe_2O_3	CaO	MgO	MnO	Al_2O_3	Fe	S	P_2O_3	Zn	CaO/SiO_2
S1	10,87	12,03	59,89	11,96	1,90	2,20	1,98	50,04	0,03	0,24	0,06	1.10
S2	10,12	10,54	58,27	11,33	2,10	2,14	1,96	49,05	0,02	0,27	0,03	1,12
S3	11,10	9,44	57,12	12,34	2,07	2,22	1,86	48,88	0,03	0,25	0,03	1,11

Table 3 shows the one-day average values of grain size and strength of the produced sinter with different carbon content in the sinter mixture.

Table 3: Grain size and strength of produced sinter in % [3].

Sinter	Sinter grain size, %		Sinter strength ISO TEST, %	
	>20mm	<5mm	TI $_{+6,3mm}$	AI $_{-0,5mm}$
S1	49,97	2,37	65,98	3,87
S2	46,94	3,14	62,16	4,45
S3	42,37	4,08	59,83	5,23

3.2. Discussion of results

The paper analyzes the important parameters that characterize the metallurgical value of the produced sinter for the needs of the technological process of iron production in the blast furnace, namely: grain size, sinter strength and FeO as an indicator of sinter reductivity.

The carbon content of the sinter mixture was 4,77% for mixture 3 and 6,11% for mixture 1. The basicity of the sinter mixture (CaO/SiO_2) ranged from 1,02 to 1,07.

The chemical composition of the sinter mixtures was quite uniform because the same ore and limestone were used.

Table 2 shows that the highest value of FeO content in sinter 1 was 12,03%, which was to be expected because sinter mixture 1 contained the highest carbon value of 6,11%, and with the increase of carbon in the sinter mixture, the FeO content in sinter increases. As the FeO content in the sinter increases, the grain size +20 mm and the strength TI $_{+6,3mm}$ of sinter increases.

4. CONCLUSION

An increase in the carbon content in the sinter mixture leads to an increase in the FeO content in the sinter. Higher FeO content in the sinter increases the strength of the sinter, which is reflected in the improvement of the increase in grain size (+20 mm) and reduces the proportion of fine fractions (-5mm) of the sinter. A smaller amount of sinter fractions below 5 mm improves the permeability conditions for blast furnace gases, resulting in higher blast furnace productivity and lower coke consumption.

Increasing the FeO content in the sinter beyond the optimal value leads to metallized sinter. Such sinter is difficult to reduce in the blast furnace, and has the effect of increasing coke consumption and reducing the productivity of the blast furnace.

For the composition of the sinter mixture, depending on the composition of the used iron ores, the optimal value of FeO in the sinter is determined, as well as its minimum and maximum value.

5. REFERENCES

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