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Professional paper

INFLUENCE OF THE RATIO OF CALCIUM OXIDE AND SILICA ON MINERALOGICAL AND PHASE CHANGES OF SINTER FROM LIMONITE ORE

Amel Zahirović, Amira Pašalić

University of Zenica, Institute "Kemal Kapetanović" Zenica

ABSTRACT

Improving the quality of iron ore sintering and adding specific components has positive effects on blast furnace productivity. Optimizing basicity in the blast furnace charge is one way to improve all indices of production processes. Adjusting basicity aims to achieve the formation of new phase compounds that are favourable for the metallurgical and mineralogical sinter properties. The chemical analyses are insufficient for controlling the phase transition of multicomponent systems, as it is necessary to know the structure of all constituents. For that reason, X-ray diffraction is used for identifying minerals in sinter. Also, the physico-mechanical properties of sinter are investigated. Based on experimental results, the optimal basicity of limonite ore from mine "Omarska" Prijedor is determined.

Keywords: basicity, sinter, calcium oxide, limonite, phase composition, XRD

Corresponding Author:
Amel Zahirović,
Institute "Kemal Kapetanović", Zenica University
Travnička cesta 2, Zenica, B&H
Tel.: +387 32 247 999
E-mail address: amel.zahirovic@unze.ba

1. INTRODUCTION

For each metallurgical process of extracting metal from ore, to make metallurgical processing possible and economical, certain conditions are set both in terms of chemical composition and in terms of metallurgical and mineralogical characteristics. Small ores, concentrates, and other small raw materials cannot be directly melted in blast furnaces but must be enlarged previously, and the most common way is sintered.

The processes of ore are thermal and take place at temperatures beginning with smelting, which enables the interconnection of mineral grains. At such high temperatures, there are chemical, structural, and mineralogical changes that improve the metallurgical characteristics of the resulting product. To achieve desired phase transformations during the sintering process, it is necessary to add specific chemical compounds during preparation, with $CaCO_3$ being one of the preferred additives. To effectively monitor phase transformations within a multicomponent system, the X-ray diffraction method proved to be the best. This method is based on the fact that any phase or component creates its characteristic X-ray signature, which depends on the specific unit cell and atomic arrangement.

2. PRODUCTION OF SINTER AT A SEMI-INDUSTRIAL PLANT

As part of the planned testing and experimentation, the Department of Ore and Iron at the 'Kemal Kapetanović' Institute of the University of Zenica conducted six experiments using different basicity levels. Sinter production was carried out using a discontinuous-type pilot plant facility with a 70

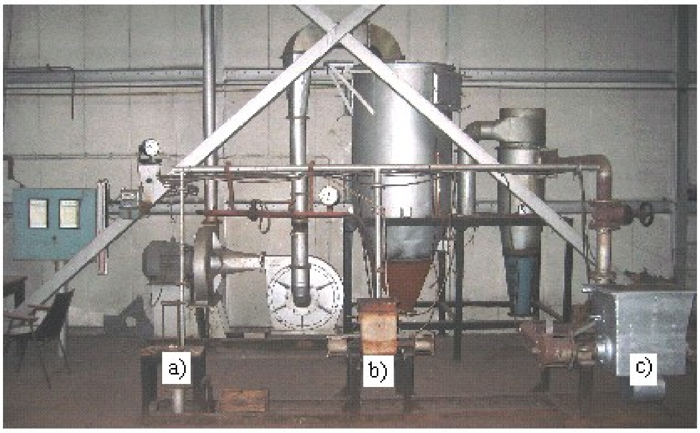

Figure 1. The semi-industrial plant with a capacity of 70 kg

Table 1. The mark of sinter mix planned basicity

Mark sintered mixtures	M1	M2	M3	M4	M5	M6
Planned basicity	0.0	0.5	1.2	1.5	2.0	2.5

kg capacity (Figure 1). The facility is designed for producing various types of sinter [5]. The mark of the sinter mix with planned basicity is shown in Table 1. Sinter was produced at the Institute. The raw materials used in the experiment are: "Omarska" limonite ore, limestone from the Grapska-Doboj site, and coke from Arcelor Mittal Zenica. All components of the sinter mixture are prepared to the extent required by the technological conditions for the production of the sinter. The produced sinter was created from a sinter mixture according to the percentage of individual components given in Table 2.

After sintering, all samples were cooled in air, and then 20 mm fractions were separated, from which samples for the XRD method were taken by quartering. The samples were tested on a Shimadzu XRD 6000 diffractometer. All samples of the obtained sinter were chemically analyzed with the components given in Table 3.

Table 2. Composition of sintered mixture

Mark of the sample	The composition of the sintered mixture, %					Basicity: CaO/SiO_2
	Iron ore Limonite	Limestone	Coke	Return sinter	Moisture	
M1	66.57	0.00	6.06	19.96	7.41	0.0004
M2	59.80	6.75	6.06	19.97	742	0.49
M3	53.32	13.86	6.12	20.16	6.54	1.20
M4	50.74	16.45	6.11	20.16	6.54	1.49
M5	47.10	20.20	6.13	20.19	6.38	2.00
M6	43.97	23.52	6.15	20.25	6.11	2.48

Table 3. Results of sinter chemical analysis

Mark of the sample	The components, %									
	Fe	FeO	Fe_2O_3	SiO_2	MgO	MnO	CaO	Al_2O_3	S	CaO/ SiO_2
A1	54.23	21.10	61.54	11.42	1.93	1.83	0.005	1.92	0.006	0.0004
A2	52.11	17.63	60.48	9.58	1.82	1.94	4.69	1.68	0.007	0.49
A3	50.10	13.92	59.07	7.86	1.62	2.44	9.43	2.16	0.010	1.20
A4	49.62	14.29	56.13	8.49	1.91	1.99	12.65	1.96	0.018	1.49
A5	47.16	10.16	58.42	8.21	1.91	1.93	17.24	1.89	0.019	2.10
A6	46.29	8.66	56.21	11.28	1.84	1.86	27.97	1.84	0.029	2.48

3. PROPERTIES OF PRODUCED SINTERS

3.1 Physical and mechanical properties of sinter

As part of the examination of the physical and mechanical properties of the sinter, a granulometric analysis was conducted using sieves with openings of 40 mm, 20 mm, 16 mm, 10 mm, and 6.3 mm. Additionally, the strength index and abrasion index were examined. Furthermore, the porosity and density of the sinter, as well as the melting and softening temperatures, were tested on the examined samples.

3.1.1 Granulometric composition for sinter

The diagram in Figure 2 shows the granulometric composition of the sinter depending on basicity. The data illustrate a direct relationship between basicity and particle size composition. As the basicity increases, the quality of the sinter decreases; that is, with a lower basicity, the granulomer composition of the sinter is better because the permeability of gases in the iron production process will be better [5-7].

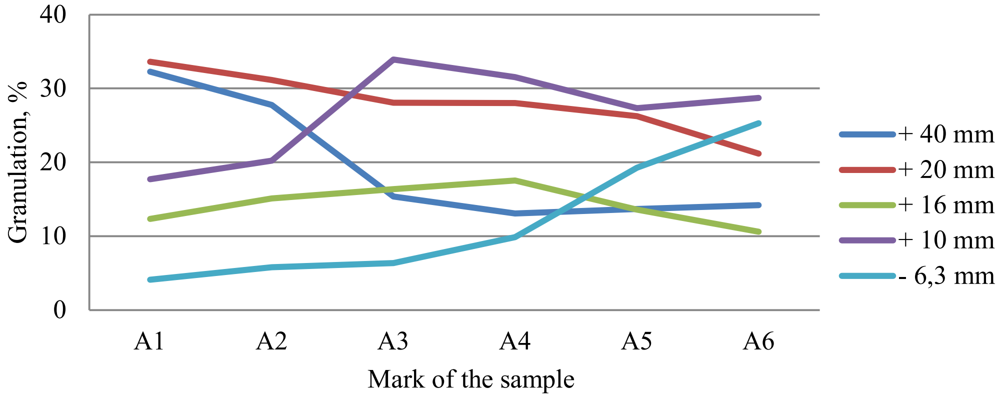

Figure 2. Particle size distribution of sinter

3.1.2 Granularity and strength of sinter

The sinter strength test is performed according to ISO TC (102)-SC3 in a drum Ø1000 mm, length 500 mm with two partitions. After rotation of 200 revolutions per minute for four minutes, sieving is carried out on sieves of 6.3 and 0.5 mm. The strength of the sinter is shown through the strength index T_i and the abrasion index A_i.

$$T_i = \frac{m_1}{m_1 + m_2 + m_3} \times 100 \quad (1)$$

$$A_i = \frac{m_3}{m_1 + m_2 + m_3} \times 100 \quad (2)$$

Where is:

T_i – strength index

A_i – abrasion index

m_1 – sample mass +6.3 mm, g
m2 – sample mass -6.3+0.5 mm, g
m3 – sample mass -0.5 mm, g

The strength index (T_i) of sinter A1 is 67.45% at a basicity of 1.2, while the strength index of sinter A3 is 74.25%. With increasing basicity, the strength index continuously decreases, and the lowest value is for sinter A6, which is 56.25% (Figure 3). The abrasion index (A_i) increased continuously with increasing basicity, and for sinter marked A5, it is around 10.93%. The best value for this parameter is around 5%.

3.1.3 The density and porosity

The results presented in Figure 4 indicate that changing the basicity has little effect on the sinter density, with only a slight change reflected in an increase in porosity ranging from 1-6%.

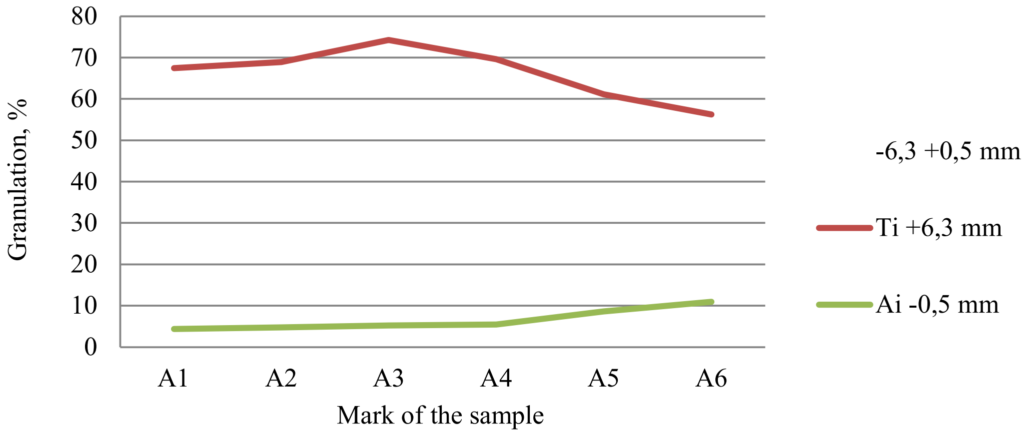

Figure 3. Graphic representation of the strength and abrasion index of sinter

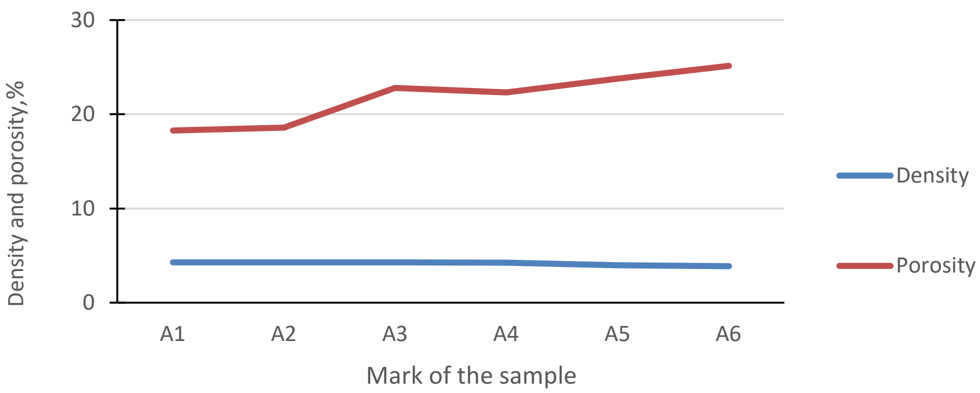

Figure 4. Graphic representation of the density and porosity of the sinter

3.1.4. Metallurgical properties of sinter

For sinter, a high melting point and a narrow softening interval are essential properties. The softening and melting temperatures are influenced by several factors, among which the most significant are mineral composition, porosity, ore type, and ore granulation. Observing the test samples of sinter, it can be concluded that the softening interval for basic sinter (A3-A6) is small, ranging from 20°C to 60°C, while for samples (A1-A2), it can extend up to 160°C.

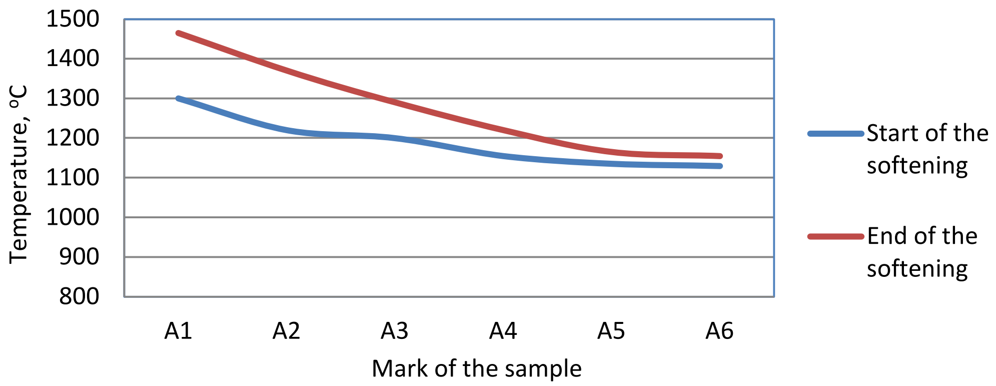

Figure 5. Graphic representation of the softening and melting temperatures of sinter

4. MONITORING THE PHASE TRANSITIONS USING X-RAY DIFFRACTION

Figures 6 to 11 show X-ray images of the obtained sinter. In Figure 6, it can be observed that magnetite predominates and plays a leading role in the mineral composition of the sinter, followed by fayalite and quartz. This is because no limestone was added during the sintering process, and instead, the natural basicity of the raw material was utilized. The results shown in Figures 7 and 8 indicate the formation of new compounds, such as hematite and SCAF (calcium silicate), as well as dicalcium silicate [4].

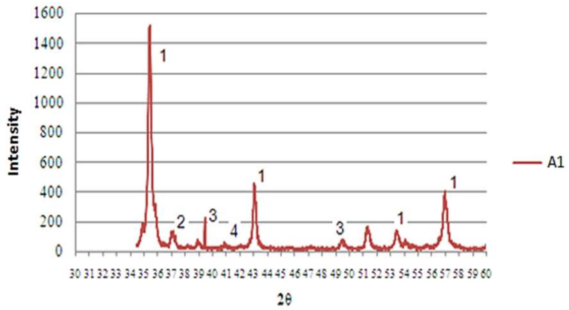

Figure 6. X-ray of sinter mark A1; 1-Magnetite, 2-Fayalite, 3-Quartz, 4-Anortite

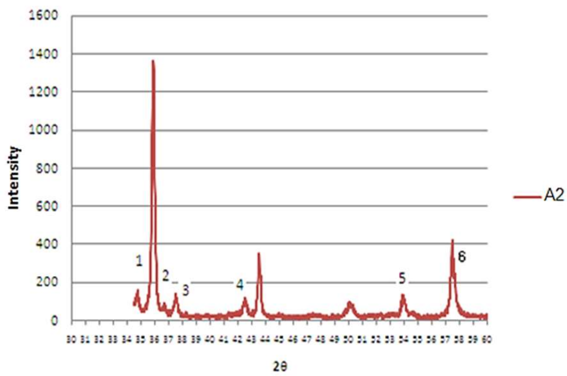

Figure 7. X-ray of sinter mark A2; 1–Magnetite, 2–SCAF, 3-Fayalite, 4-Anorthite, 5- Hematite, 6-Calcite

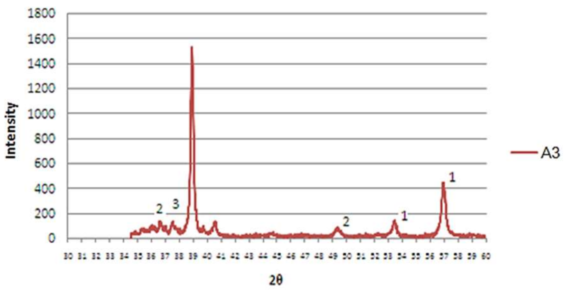

Figure 8. X-ray of sinter mark A3; 1-Magnetite, 2-Dicalcium silicate, 3-Anortite

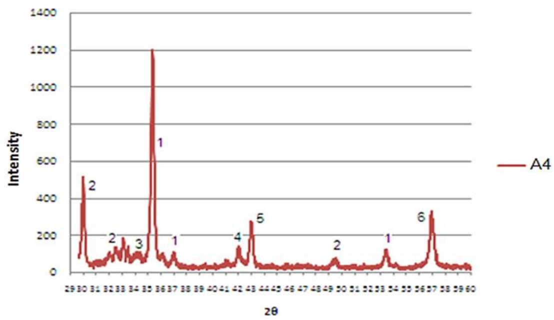

Figure 9. X-ray of the sinter mark A4; 1-Magnetite, 2-Dicalcium silicate, 3-SCAF, 4-Wustite, 5-Perclase, 6-Calcite

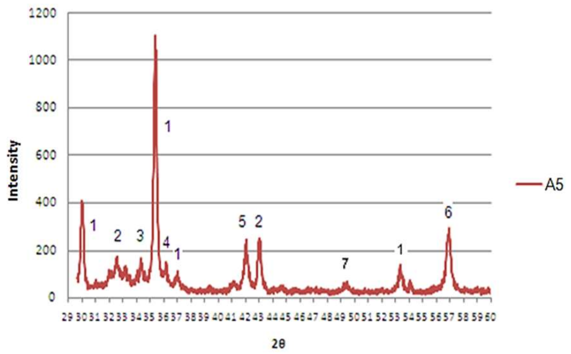

Figure 10. X-ray of sinter mark A5; 1-Magnetite, 2-Dicalcium silicate, 3-SCAF, 4-Wustite, 5-Periclase, 6-Calcite

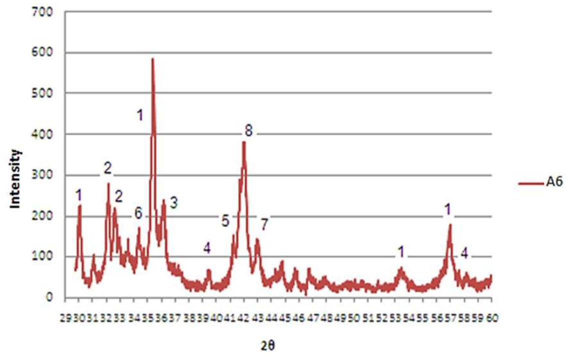

Figure 11. X-ray of the sinter mark A6; 1-Magnetite, 2-Dicalcium silicate, 3-SCAF, 4-Calcite, 5-Hematite, 6-Anortite, 7-Periclase, 8-Wustite

In Figure 9, a new phase can be noted as a result of the addition of limestone or increasing basicity through periclase and FeO-wustite, which was created after the completion of the magnetite reduction.

The results shown in Figures 10 and 11 demonstrate that an increase in basicity leads to a change in the mineral composition of the sinter. Fayalite essentially binds into other compounds or disappears. This happens because all the calcium ferrite is converted into calcium silicate [4].

5. CONCLUSIONS

Based on the results of the tests, it can be concluded that basicity significantly modifies the properties of sinter. It can be observed that the granulometric composition quality deteriorates with increasing basicity. The abrasion index and strength index are acceptable only for sinters labeled A3 and A4. An increase in basicity results in a moderate increase in porosity, while the sinter density remains unchanged. It can be concluded that changes in basicity have a significant impact on the onset and end of sinter softening. Specifically, the sintering softening interval decreases with increasing basicity. Based on the experiments and the results obtained from the research, it is concluded that the optimal basicity for the used raw materials (Limonite from Prijedor, coke from Zenica, and Dolomite from Doboj) is 1.2, marked as A3. Increasing or decreasing the basicity from the optimal value would lead to a deterioration in the properties of the sinter and could disrupt the potential iron production process.

Conflicts of Interest

The authors declare no conflict of interest.

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