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[1.] Laura-Mihaela MILITARU, [2.] Paul Petruș MOGOȘ, [3.] Nicolae CONSTANTIN, [4.] Sinziana ITTU, [5.] Denisa-Elena ANCA, [6.] Lavinia-Marilena HARCEA

STUDY FOR EVALUATION AND OPTIMIZATION OF MINERAL COMPOSITION AND STRUCTURE OF IRON ORE GRANULATION IN SINTERING PROCESS

[1-6.] University Politechnica of Bucharest, ROMANIA

Abstract: The characterization of iron ore particles is vital importance for the studies of the mineral composition. The specific surface area of iron ore particles can be measured by laser diffraction, and mathematical models (based on the size distribution). Particle size fractions and chemical composition were determined of several types of iron ore (symbolically marked A, B, C, D, E, F). These features have direct influence on the sintering process by particle size analysis, permeability, reducibility, porosity, CaO/SiO ratio, influence of MnO in sinter. The granulation experiment show that these minerals (more than 50% with diameters of <1mm) can be successfully used in the sintering process, or by alloying with other minerals in Europe. Large irregularly shaped and adhesive particles can get a higher efficiency of granulation easily. The usage of iron ore with big and rough particles can improve the permeability while the iron ore with smooth and sphere particles has poor ability of granulation.
Keywords: iron ore, sinter, size distribution, chemical composition, mathematical model

1. INTRODUCTION

The performance of blast furnace depend, to a greater extent, on the physical and chemical characteristics of the burden materials and their consistency. Sinter constitutes 70–80% of the iron bearing burden material in the modern blast furnaces (Figure 1). An important aspect of the sinter, as ferrous burden, is that it could be tailor made. Its physical & chemical properties depend on the properties of individual components and on its micro-structure, especially on the size, shape distribution and the mutual interaction of the individual components. A thorough appreciation of the microstructure of sinter is a basic necessity and the first step towards establishing structure–property relationship.

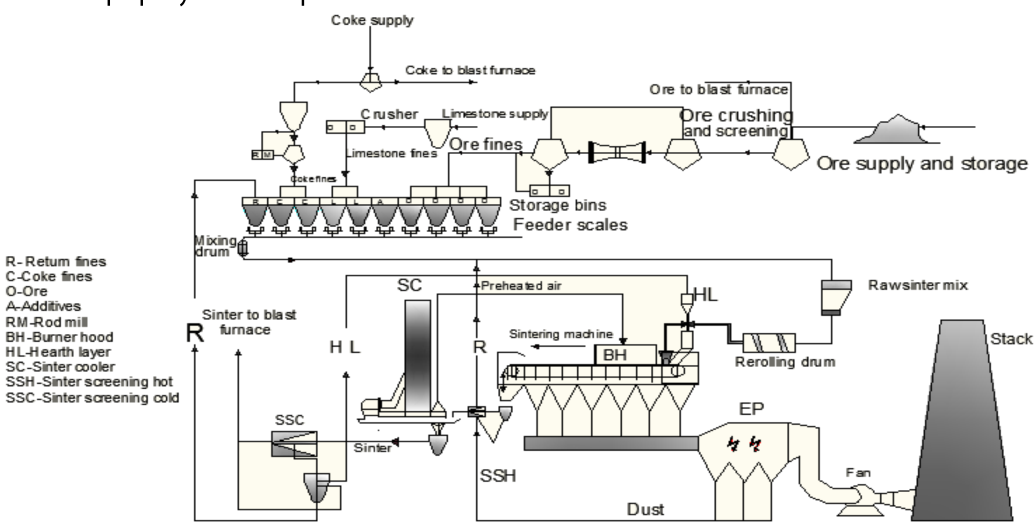

Figure 1. Schematic diagram of the sintering process

Sinter is agglomerate made of fine iron ore that is cheaper than pellets and lump iron ore and is superior in terms of reducibility and dropping characteristics. For the two reasons of better production cost performance and stable operation of blast furnaces, sinter has been used in many countries as one of the main sources for blast furnace operation. In order to satisfy the need to improve the productivity of sinter, a broad range of research and development efforts have been made from the viewpoints of the technology to pre-treat fine iron ore and the technology to control the charging structure on the entire spread of the sintering bed.

The characterization of the particle size and the surface features of iron ores is of vital importance for the studies of mineral processing. The specific surface area of iron ore particles can be measured laser diffraction, and mathematical models based on the size distribution. However, what is the difference among these methods and what is the indication of the results were less discussed on the iron ore granulation, which is the right topic of the present study.

With the progressive deterioration in the quality of iron ore in recent years, there has been an increase in the quantity of pisolite ore used in the raw material mix. It is known that the use of large quantities of these ores as sinter raw materials greatly reduces the granulation and air permeability of the raw material packed bed, resulting in reduced productivity. This is thought to be because these ores are porous and the added moisture is absorbed into the ore particles, with the result that the volume of moisture is not sufficient for granulation. Accordingly, to ensure the stable use of large quantities of these ores, it is necessary to optimize the adding volume of moisture. Accordingly, it takes a certain period to stabilize the optimal moisture value, and this was one factor in producing instability in the operations.

2. MATERIALS AND METHODS

Properties of iron ore sample related to granulation were measured from different locations: A, B, C, D, E, F. Diffraction shows that all are in compositions a significant amount of Fe (from 64.2% to 68.3%). Minerals present in raw materials are: are goethite, hydrated iron oxide, hematite, kaolinite and quartz.

2.1. Particle Size Measurement

Samples of iron ore properties related to grain are presented in Table 1, Figure 2, for each sample separately, using laser diffraction. Parameters follow:

- = mixture sintering;
- = CaO/SiO_2 report;

In the present study, six samples of the iron ore were selected for the measurements. Samples were analyzed by particle size, analysis that was performed in a 0.5kg volume of each sample determining the particle size classes between 63µm-8mm. Particle size distribution for each type of ore is presented in Table 2 and Figure 3. In terms of grain more than 50% of the particles are>1mm which contributes to the sintering process by high productivity and permeability. Also we observe a significant percentage of fine ore, but they may become adherent particles, increasing the diameter.

Table 1. Particles size analyzed

Size (µ)	Ore A	Ore B	Ore C	Ore D	Ore E	Ore F
8 mm	2	2	6	2	20	21
4 mm	8	7	24	7	14	12
2 mm	0	0	0	20	12	5
1 mm	31	48	26	30	12	9
500µm	0	0	10	13	10	10
250 µm	0	0	8	11	0	0
180 µm	22	27	4	4	13	17
90 µm	12	4	6	5	4	7
63 µm	10	0	15	8	3	5
63µm	15	12	0	0	11	11

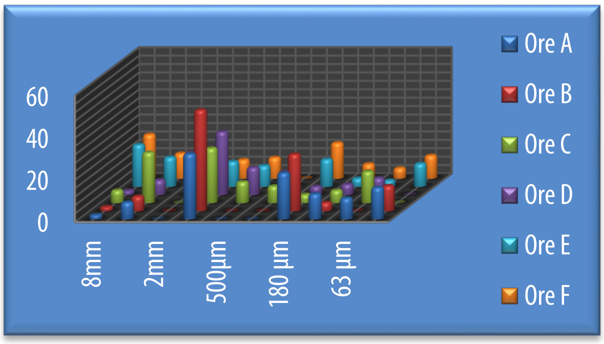

Figure 2. Particles size distribution

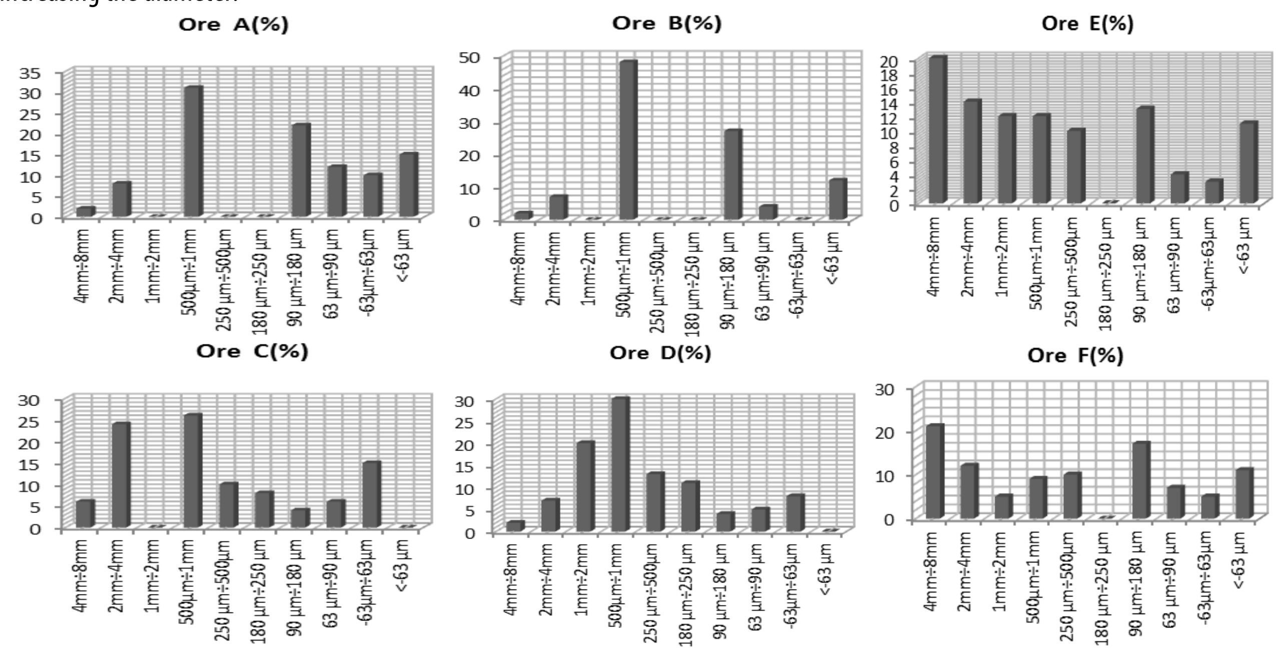

Figure 3. Variation of particle size fraction for each component separately

Table 2. Particles size distribution

Size(µ)	Ore A(%)	Ore B(%)	Ore C(%)	Ore D(%)	Ore E(%)	Ore F(%)
4mm÷8mm	2	2	6	2	20	21
2mm÷4mm	8	7	24	7	14	12
1mm÷2mm	0	0	0	20	12	5
500µm÷1mm	31	48	26	30	12	9
250 µm÷500µm	0	0	10	13	10	10
180 µm÷250 µm	0	0	8	11	0	0
90 µm÷180 µm	22	27	4	4	13	17
63 µm÷90 µm	12	4	6	5	4	7
-63µm÷63µm	10	0	15	8	3	5
<-63 µm	15	12	0	0	11	11

2.2. Mathematical analysis

According to Figure 1 samples A, B, C, D, E, F, are fine ore. Surfaces of ore samples can be mathematical calculated with formula (1), assuming that most of the sample particles are spheres, as follows:

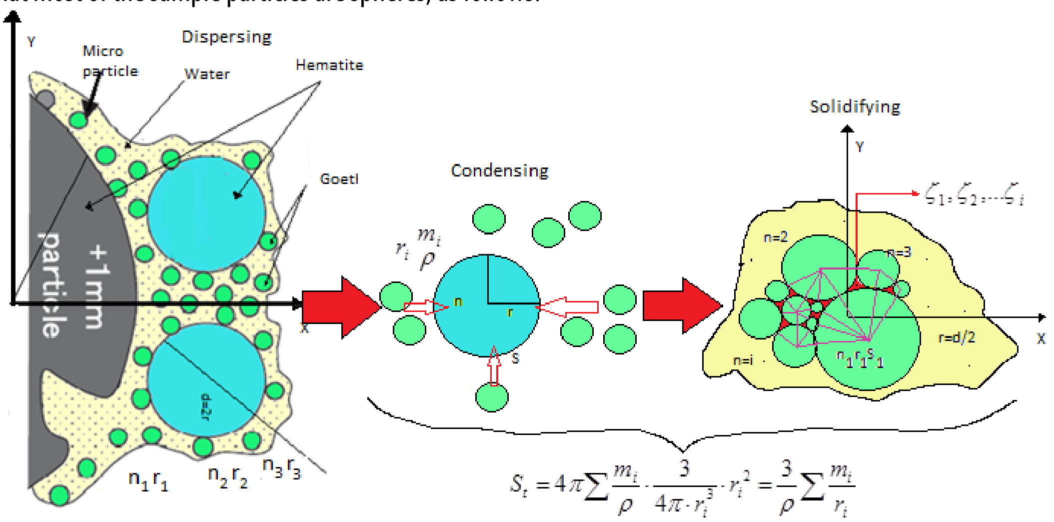

Figure 4. Mathematical calculation of particle diameter

$$S = 4\pi \cdot n \cdot r^2 \qquad (1)$$

where : *S* is the total surface area of all particles of unit mass, *r* is the radius of the particles.
Assuming that in this experiment will have *i* particles, our formula will become:

$$S_1 = 4\pi \cdot n_1 \cdot r_1^2 \qquad (2)$$

$$S_2 = 4\pi \cdot n_2 \cdot r_2^2 \qquad (3)$$

....

$$S_i = 4\pi \cdot n_i \cdot r_i^2 \qquad (4)$$

$$S_{1+2+3+...+i} = 4\pi \sum n_i \cdot r_i^2 \qquad (5)$$

The total number of particles n_i can be calculated by the relationship:

$$n_i = \frac{m_i}{\rho} \cdot \frac{3}{4\pi \cdot r_i^3}$$

$$S_t = 4\pi \sum \frac{m_i}{\rho} \cdot \frac{3}{4\pi \cdot r_i^3} \cdot r_i^2 = \frac{3}{\rho} \sum \frac{m_i}{r_i}$$

where *m* is the mass of particles of *r* radius compared to a mixture of 100g raw density ρ .

We can determine the diameters for each particle. At the same time, with increasing particle diameter (fundamental step in preparing sintering) we see the emergence of a new size ξ- mathematical model imperfections (open spaces) shown in Figure 5.

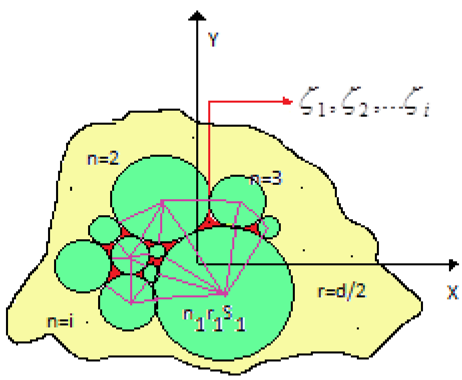

Figure 5. Increasing particle diameter

We can express relationships depending particles diameters:

$$\sum r_i^2 = \frac{S_1}{4\pi\cdot n_1}+\frac{S_2}{4\pi\cdot n_2}+...+\frac{S_i}{4\pi\cdot n_i}$$

$$\sum r_i^2 = \frac{1}{4\pi}\sum\frac{S_i}{n_i} \qquad \sum 4r_i^2 = \frac{1}{\pi}\sum\frac{S_i}{n_i}$$

$$\sum 2r_i = \frac{\sqrt{\pi}}{\pi}\sqrt{\sum\frac{S_i}{n_i}}$$

If we noted, $d = 2r$, $r \geq 0$, the diameter of each particle; S_ξ -surface imperfections, S_s -sintering surface, the relationship becomes:

$$\sum d_i = \frac{\sqrt{\pi}}{\pi}\sqrt{\sum\frac{S_i}{n_i}}$$

$$S_s = S_i - S_\zeta$$

Table 3. Chemical composition of ores

Chemical composition	Ore A	Ore B	Ore C	Ore D	Ore E	Ore F
Fe	64.2	67.2	68.3	64.7	64.5	65.2
SiO_2	5.1	0.6	1.3	4	4.2	4.2
Al_2O_3	1	0.94	0.9	1.1	0.7	0.8
TiO_2	0.08	0.03	0.04	0.03	0.07	0.09
CaO	0.02	0.01	0.03	0.05	0.02	0.03
MgO	0.03	0.02	0.04	0.05	0.04	0.05
Na_2O	0.005	0.01	0.006	0.02	0.006	0.006
K_2O	0.008	0.01	0.004	0.01	0.006	0.007
Mn	0.2	0.45	0.229	0.2	0.07	0.07
P	0.045	0.037	0.03	0.04	0.057	0.04
S	0.007	0.01	0.005	0.005	0.006	0.006
V	0	0	0.006	0	0	0
LOI	1.5	1.4	0.61	0.05	2.3	1.5

Note that with the migration of particles, $\xi \longrightarrow 0$ (reducing the distances between particles). This is necessary because small diameter particles, spherical have a low grip and we have trouble in sintering process. This is necessary to obtain particles with large diameters and high porosity mathematical method.

2.3. Chemical composition analysis

Chemical composition of the 6 types of ore is given in Table 3, Figure 6. In all 6 samples over 50% of chemical composition is owned by Fe, dominated by raw materials with a low basicity and MgO content between 0.02% -0.05%.

The significant amount of iron holds ore C, and the lowest ore A. We see a inverse distribution the amount of Fe with the SiO_2 in that ore with a high quantity of Fe corresponds a small amount of SiO_2, ore C with 1.3% SiO_2 and 68.3% Fe, respectively ore A with 5.1% SiO2 and 64.2% Fe.

Chemical composition shows that these types of ores can be successfully used in the sintering process. Meet one ore with a SiO_2 content <1%, as-Al_2O_3 can be used to reduce ores containing SiO_2 or in combination with Australian ore, where it prevails, and can be successfully used in Europe and the Far East. P and Mn level is moderate, and the basic oxides level is very low for these types of ores (MgO and CaO). The S, V, and other impurities level is very low.

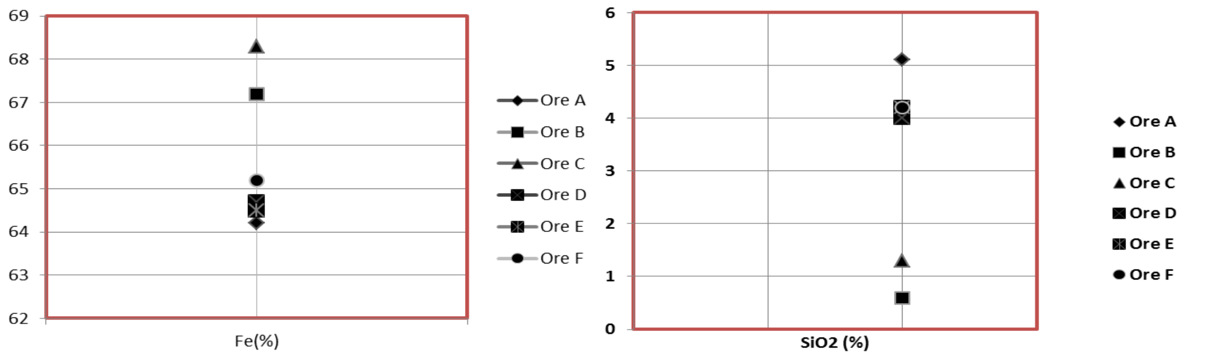

Figure 6. Fe and SiO_2 distribution in the samples analyzed.

Table 9. Alkalinity variation

Chemical composition	Ore A	Ore B	Ore C	Ore D	Ore E	Ore F
CaO/SiO2	0.004	0.017	0.0231	0.013	0.0048	0.007
ΣOa	5.18	0.63	1.34	4.03	4.27	4.29
ΣOb	1.063	0.99	0.98	1.23	0.772	0.893
ΣEd	0.007	0.01	0.011	0.005	0.006	0.006
ΣOb/ΣOa	0.205	1.571	0.7313	0.305	0.1808	0.208

The alkalinity level is low, mainly due to high amount of SiO_2 in ore A, D, E and F. Table 4 and Figure 7 shows the distribution of alkalinity in the type of ore. Minimum values <0.01 are typical for ore A, E and F and the maximum for ore C at a rate of CaO/SiO2 = 0.023.

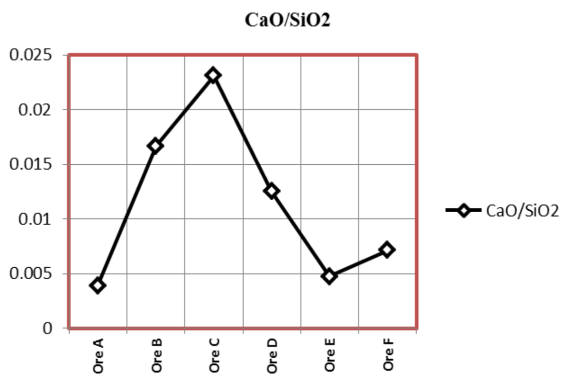

Figure 7. Alkalinity evolution depending on the type of ore

3. CONCLUSIONS

In preparation for sintering is required particle size analysis for quality and high efficiency of processes.

Particles with a small diameter can be used for the sintering process after a previous training, their measurement can be done by diffraction or mathematical into developing comparative simulation models needed later to develop the first fusion iron.

The difference between the 2 measurements is that if the mathematical model size $\xi \rightarrow 0$ (the spaces between particles shrinks iron ore with small and spherical diameter have low grain capacity), in practical measurements $\xi \neq 0$ because the efficiency of grain increases with increasing water saturation and iron ore.

Size ξ depends on the homogeneity of particle size, shape, total and initial surface sintering bed.

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