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GENERATION, MORPHOLOGY AND MINERALOGY OF THE DUST PARTICLES FROM OFF-GAS BLAST FURNACE

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ABSTRACT

In order to elucidate the morphology and mineralogy of the dust from blast furnace, the fundamental aspects of its generation process were studied. A dust generated by the dry dedusting step of the cleaning process for the BF off-gas was analysed by microscopy and chemical analyses. The results indicated that the shape of particles is predominantly non-regular. We established with approximation the main mineralogical compounds: hematite, magnetite, calcium ferrites, glass and silicate phases. These are in accordance with mineralogy of the feed materials charged into blast furnace and in correlation with the complex processes that are developed into specifical zones where the dust particles were generated. The properties of BF dust and its structural phases are discused in respect to the blast furnace processes, the temperature zones and the gas composition.

KEYWORDS: integrated steelwork, BF dust, structural properties, mineralogy, shape of particles, valorisation, sintering process

1. Introduction

The knowledge of the mineralogical characteristics of the dust from blast furnace is necessary to create the fundamentals that can be utilized to design the dust recycling technology. Also, this is necessary for good knowledge of the waste in respect to making the forecast that is its behavior into a recycling flow, in this case in the sinter plant by feeding directly to the mixing beds.

The dust and sludge are generated from the off-gas of the blast furnaces. This is cleaned in 2 steps. In the first step, that is the dry dedusting step, the coarse particles are separated so that the BF dust is formed. After passing the first step of the cleaning process, the off-gas is cleaned in a wet process. The fine particles are separated in this way and the BF sludge is generated.

As result of the diverse phenomena that occur in the different zones of the blast furnace, the powder mixes are formed from a part of the varied materials charged into the blast furnace such as feed materials. These are collected in the hot ascendent gases that pass up the descendent charge materials. The dust quantity and its properties is in accordance with its generation process in respect to the blast furnace processes (the temperature zones and the gas composition, Figure 1).

Also, the caracteristics of the BF dust genered are influenced by the nature, the quantity and the properties (chemical composition, mechanical strengh) of the feed materials (sinter, iron ores, fluxes, coal injected).

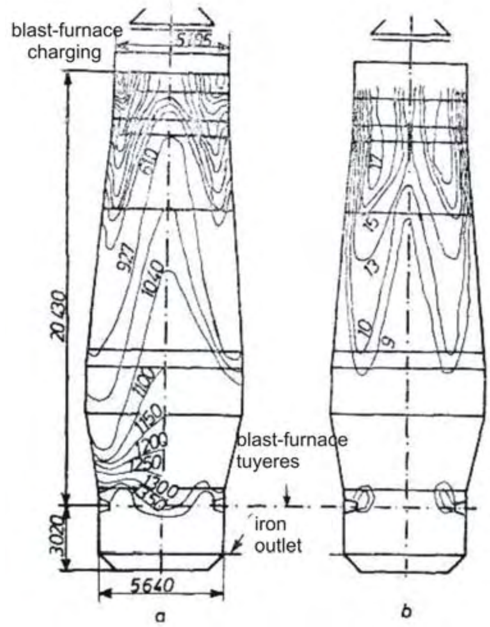


Fig.1. *Temperature (a) and the CO content (b) of the gas into a section of the blast furnace [1].*

The properties of the dust particles and the properties of the feed materials from the blast furnace, that is the generator for this dust, are likewise. Supplementary it is necessary to take into consideration the zones where the dust particles are generated and the zones which are passed by the dust particles until their collecting in the dust catcher. The temperatures and the composition of the gas are different and transformations are developed in the dust particles (for example the disintegration of the sinter and the iron ores, attributed to the volume change associated with the reduction of hematite to magnetite).

The descending of the charge materials is accompanied by physical changes and chemical reactions, Figure 2. A lot of mechanical processes occur: abrasion, crushing, cracking. Also, the softening of materials, the formation of the liquid phases and, interactions between the gases, liquids and solides can occur. The reduction processes and oxidation are produced and these are specific for each zone of the blast furnace, according to its temperature and its composition of the gases generated now by coke (the lower, middle and upperzone).

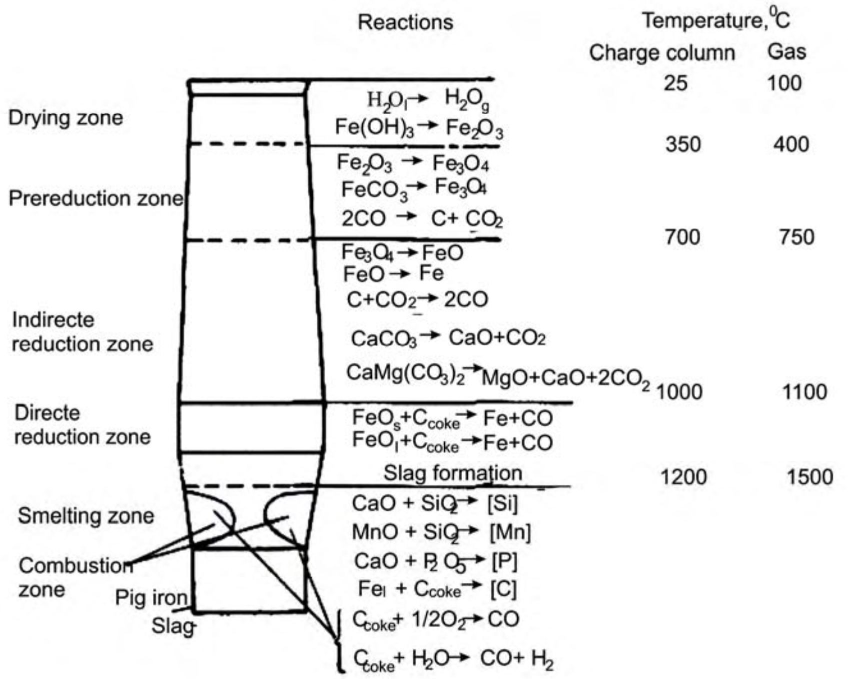


Fig.2. *Chemical reactions that are taking place in the zones of the blast furnace [1]*

The formation of the dust particle in the zone that have lower temperatures (so called upper zone or preparation zone where the ascending gas decreases in temperature to about 250^{0}C and the solids temperature rises from the ambient temperature to about 800^{0}C) is accompanied by the decomposition of carbonates other than calcium, vaporization of moisture and hydrated water of the burden, carbon deposition according $2CO = CO_2 + C$ and partial or complete reduction of hematite as well as magnetite into their lower oxides.

The most part of the coarse particles are formed from the particles of the feed materials (sinter particles, iron ore particles, flux particles, carbon and ash from coke or powder coal), the carbon black from the processes passed into upper zone of the charge column, the volatile mass of the powder coal (that is injected into tuyeres and condensed at the surface of the dust particles), hygroscopic water and residual capillary.

For an integrated steel plant with the sintering plant as upstream facility, the BF dust is internally valorized. The dust is generally recycled at the sinter making in more advanced countries. In this case, the BF dust together with other iron bearing materials are utilised into sinter feed. For good results, a special process of micro-pelletisation of the sinter feed into the mixing drum followed by sintering process must be considered [2, 3].

On other hand, the iron sinter and iron ores are introduced into BF furnace to produce molten iron. The most important factor that conditioned the good BF furnace function is the quality of each feed material component. The sinter quality is dependent on the properties of all components that formed the sinter mix. The chemistry of the iron-bearing materials and the variation in process parameters decide the sinter structure which, in turn, governs the sinter quality. Therefore, it is important to know which is the chemical composition and the mineralogical structure for the iron-bearing components, and also for the BF dust. Their knowledge gives the possibility to forecast their behaviour durring the sintering process. In our case, this is very important in the evaluation of valorization solution for the dust of blast furnace in the sintering process. This paper presents the mineralogy of the dust from blast furnace in accordance with its morphology. The fundamental aspects of its generation process were studied.

2. Experimental method and materials

In the investigations, we used samples of BF dust taken from the discharge of the de-dusting unit. After homogenization by stirring and reduction of mass by quartering, the sample was reduced to a necessary size. The average chemical composition of BF dust samples, determined by classical quantitative methods is given in Table 1.

Table 1. *Average chemical composition of BF dust, % wt*

Fe	Mn	SiO_2	CaO	MgO	Al_2O_3	C	P	S	Oily mass
28.20	0.50	7.00	5.66	0.98	2.40	44.27	0.030	0.32	0.70

The powdery material was included into the synthetic resin and for obtaining a flattening surface, the samples were polished. The reflected-light micrographs of the dust samples were analyzed with optical microscope OLYMPUS and NEPHOT. Also, the dust samples were thermally treated and then were structurally analyzed.

The parameters of this treatment were: ~1100 ^oC for the heating temperature, 2 hours maintaining time, 20 minutes for cooling at the ambient temperature.

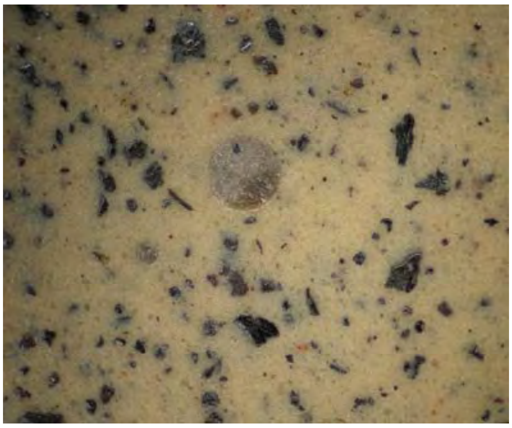
For correct approximation of the main mineralogic compounds, the results of the analyses that meet the requirements of international standard specifications for the magnetic fraction and CaO free content were used [4, 5].

Fig.3. *Dust BF sample*

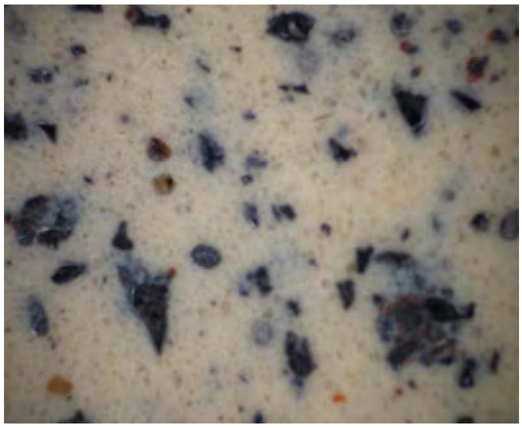
3. Results and discussion

The macroscopic structure of dusts analyzed is non-uniform, with large pores and high permeability, Figure 3.

In respect to morphology and their different origin, the BF dust particles have varied shapes and dimensions. A lot of BF dust particles have polyhedral shapes and some of these have rounded shapes (a little proportion), Figure 4.



(x50)



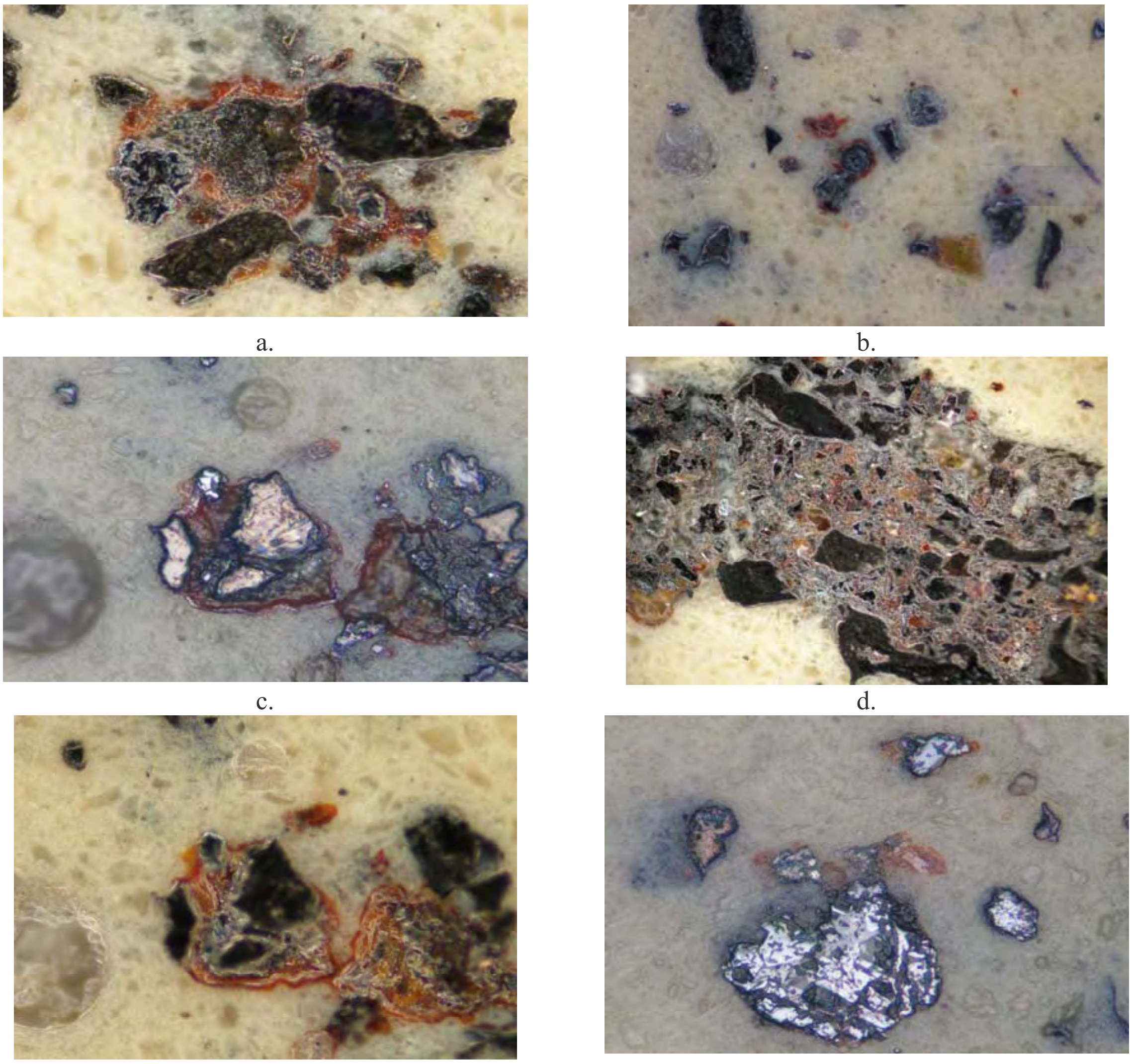
(x110)

Fig.4. *BF dust particles with varied shapes (polyhedral shapes and rounded)*

According to the researches reported by other references about the sintering process, the particles of the ferrous materials with irregular polyhedral shapes have the better adherence capacity on the bigger particles considered as nucleus for the process. This aspect is specific for the preparation step of the sintering flow that is referred to the mixing operations by simultaneous balling and wetting of fine materials into mixing drum. These various materials formed by particles with various sizes and shapes are homogenized. As result of the wetting, the fine and small particles are covered with a water layer and then by adherence under superficial tension and balling acts, the micropellets are formed.

For BF dust samples, the particles with polyhedral shapes are prevalent. As a result, the following forecast is possible: the BF dust will have a good behavior during the preparation process of the feeding materials. Also the formation speed of the micropellets is favorably influenced by the presence of the polyhedral particles.

The generation process of the dust and the mineralogy of feed materials charged into blast furnace must be considered for establish the phase composition of the BF dust particles. The micrographs of the BF dust samples are given in Figure 5. Main phases include hematite, magnetite, ferrites, glass, and silicate phases.



a. b. c. d. e. f.

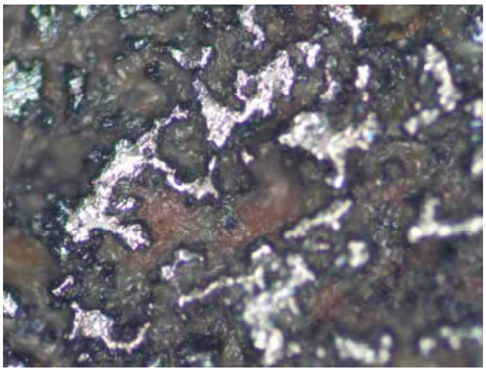
Fig.5. *Reflected-light micrographs of BF dust structure: a. magnetite, hematite set in partially devitrified glass, ghelenit, silicoferrite of calcium and aluminium (x400); b. magnetite, hematite, ghelenit, wallostonit (x200); c. magnetite, hematite, wallostonit (x400); d. magnetite, hematite, ghelenit, olivine, calcium ferrite crystals with interstitial calcium orthosilicate (x200); e. magnetite, hematite, wallostonit (x400); f. magnetite, hematite (x400)*

All feed materials components of the BF charge, namely the iron ores and sinter, transfer their mineralogy to the mineralogical structure of the BF dust particles. Also these are influenced by the presence of the lime, coke, and pulverized fine coal. The variations in compositions of the raw materials and their heterogeneity also play a big role in the heterogeneity of the phase composition of the BF dust. Additionally this is influenced by the physical, thermal and chemical processes that take place in the zones of the blast furnace height.

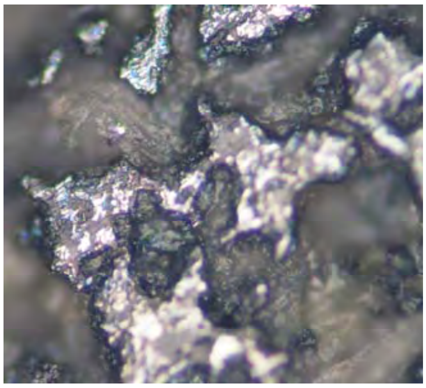
Firstly the structural phases of the superior iron oxides are present, magnetite and secondary types of hematite are the prevalent phases. Wustite is absent because an oxidation process takes place into the cold zone of the off-gas cleaning system. Wustite formed in the first step at the exit of the gas is reoxidated, this process is positivelly influenced by the great surface of the BF dust particles. For summarysing, together with the iron prelevant phases (magnetite and hematite), there are present other phases such as ghelenit, wallostonit, olivine. Circumstantially, the fine coal particles that pass nonburned through the column of the feed materials can be present in the dust [5].

To estimate the phase composition, can be used the results of the magnetic fraction pattern and the free CaO content for the BF dust analyzed. The magnetic separation is possible for materials that have mineralogical components with different magnetic properties. This difference is in accordance with iron oxide types and its proportion into BF dust. According to the low value (11.15%) of the magnetic fraction for the material analyzed, the BF dust is a weak magnetic material like hematite ore, limonite and siderite. For BF dust, an important quantity of CaO forms chemical combinations (ferrite of calcium, wallostonit, and olivine). Other quantity of CaO is free (1.27 %wt or 24.44 % of total quantity) and for consequence the decreasing of the lime addition for self-fluxing sinter is possible.

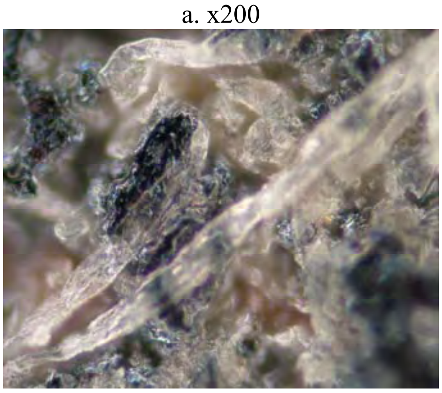
The recycling of the BF dust in the sinter plant by feeding directly to the mixing beds involves structural transformations of its particles [6]. To establish the approximate morphological and mineralogical changes that are produced in the BF dust particles after the sintering process, the samples were heated at ~ 1100 ^{0}C, held at this temperature, and cooled down (the cooler time was 10 – 20 min). The oxygen from the atmosphere furnace and the high carbon of the BF dust leads to the structural modifications for the samples that are thermally treated. The transformations can be attributed to calcination losses associated with carbon oxidation, oily mass, other physical and chemical processes. The micrographs of the BF dust samples are given in Figure 6.



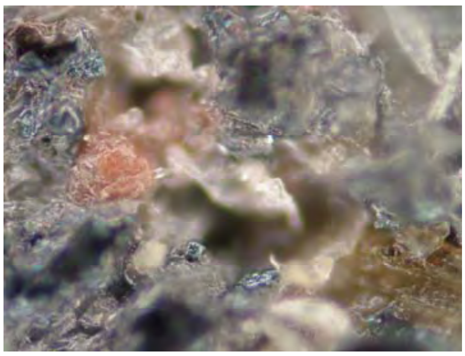
a. x200



b. x400



d. x400



e. x400

Fig.6. *Micrographs of BF dust samples thermally treated: a. magnetite with partially reoxidized zones of lamellar hematite; matrix of glass and crystallized phases of silicoferrite of calcium and aluminium-SFCA, olivine, wallostonit*

4. Conclusions

The sintering process can be the best solution for BF dust recycling for an integrated steel work. This is determined by properties of the dust (chemical composition, particles shape, morphology, and structure) because the sinter quality is dependent on the properties of all components that formed the sinter mix. The dust properties are influenced by its generation process: feed materials components of the blast furnace, the physical and chemical phenomena that occur in the different zones of the blast furnace and cleaning system etc.

For the samples analyzed the majority of the dust particles have irregular polyhedral shapes. This shape of iron components leads to a good behavior during the preparation process of the feeding materials for sintering process. The main mineralogic compounds of the BF dust particles are transformed hematite, magnetite, calcium ferrites, glass and silicate phases. These are similar to the mineralogical structure of the feed materials components of the blast furnace. The structural transformations that occur in the dust particles at the thermal treatment, oxygen presence and carbon are similar to those are passed into components that formed the sinter mix.

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