CHARACTERIZATION OF BOF DUST FOR PELLETS PRODUCTION USED IN BLAST FURNACE

E.P. da Rocha[1], J.A. de Castro[2], G.M. Araujo[3], L. Martins[4]
[1,2,3,4]UFF- Universidade Federal Fluminense
elisa_procha@yahoo.com.br

ABSTRACT

In order to minimize the incorrect disposal of dust generated in basic oxygen furnace (BOF) converter and to generate a new application for this solid residue a simple characterization route is proposed. The powder residue is used to produce self-reducing pellets and can be used in the blast furnace process. The chemical analysis of the sample was carried out using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), and some elements as Fe, Si, P, Al and Ca were detected with higher amount identified as iron achieving about 65%. Moreover, the X-ray diffraction analysis indicated that iron reach phases are composed mainly as magnetite (Fe_3O_4) and hematite (Fe_2O_3) while quartz (SiO_2) and calcite ($CaCO_3$) where the major impurities. The spectrometry dispersive energy(SDE) analysis confirmed the presence of such elements and the images obtained by SEM allowed visualizing the morphology of the particles. The average of particle size distribution of the dust was 0,053 mm which is suitable for self-agglomerates pellets.

Key words: BOF dust, self-reducing pellets, characterization.

1 INTRODUCTION

During the oxygen blowing process in BOF converter, the gas carries the solid micro-particles for the ventilation system, as shown in Figure 1. Subsequently, these particles are captured and washed, generating slurry which must be treated for correct destination of waste.

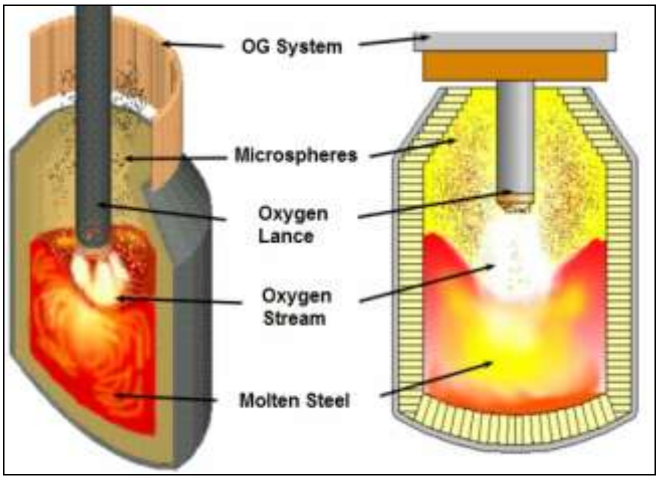


Figure 1. Generation of dust in BOF conversor*.
* Mendes, 2009[1]

According to the Figure 1, the pig iron with high content of carbon contact oxygen and produces CO/CO_2 while small droplets of liquid freeze forming fines micro-particles that are carried by the gas and need to be removed from off-gases furnace in cleaning system. The total amount of these fine particles generated in the process is about 3-30 kg/t of pig iron treated, depending on the operational practice[1].

In accordance with several previous work[2,3,4,5] phases like magnetite (Fe_3O_4), wustite(FeO), calcium oxide (CaO), zincite (ZnO), metalic iron particles and quartz (SiO_2) are usually detected in this powder. Table 1 shows typical chemical composition of this materials [4,5].

Table 1. Chemical composition of BOF dust, according sources [4,5].

Compounds	wt. % (1)	wt. % (2)	wt. % (3)	wt. % (4)
Total Fe	55.4	47.9	60.26	46.9
$Fe_{metalic}$	-	-	4.9	2.2
Fe_2O_3	-	-	5.25	44.4
Fe_3O_4	-	-	-	0.3
FeO	-	-	66.48	-
SiO_2	2.3	1.4	4.25	2.0
MnO	1.8	0.3	-	3.4
CaO	10.6	13.0	12.90	23.2
MgO	3.7	0.5	5.60	2.1
ZnO	1.7	6.7	-	1.9

PbO	-	0.5	-	0.1
Na_2O	0.3	0.7	-	-

It can be observed in Table 1 that the iron present in this kind of dust can varies from 40 to 60%, which is attractive to be used as raw materials for previous processes of the steel mill such as sintering and blast furnace or BOF. Furthermore, due to the high amount of calcium oxide usually present in this dust, it is possible to reduce the binder used in pellets or sintering production.

Takano, C. (3) in his work, verifies that recycling of steel wastes containing iron, as self-reducing agglomerates is economically and technically feasible.

The agglomerates would be used to replace partially the scraps charged in BOF converter and the economic return would be of the order of US$ 10 a US$ 20 per ton of reused waste.

2 MATERIALS AND METHODS

First, the dust was manually homogenized using alternating quarters method following, the sample was chemically and morphologically characterized and the analysis of size distribution using granulometric distribution procedure was performed.

2.1 Chemical Characterization

The chemical analysis was performed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP), model Genesis, available in Centro de Tecnologia Mineral (CETEM), in UFRJ. For perform ICP analysis the sample was digested in aqua regia for 24 hours and diluted in distilled water.

SDE analysis (Spectrometry Dispersive Energy*)* was carried out to corroborates the components identified by ICP method. The spectra acquisition was accomplished by Smart SEM software in a scanning electronic microscope Zeiss EVO MA 10 and coupled X-ray detector EDAX.

The adjustment parameters of the camera were constant for a representative field of the sample. Furthermore, the images obtained by SEM were used to identify the iron oxides present and were confirmed by a spot scanning in the region of the analysis. For images acquisition, the sample was coated with gold. The images were acquired by secondary electrons (SE) applying a 20kV voltage and using a work distance of 13.0mm; and back-scattered electron detector (BSE) with a 16kV voltage and distance work of 12.5mm.

The phase identification performed with the aid of an X-ray diffractometer XRD-6000 Shimazu, which allowed to comprehend how the components identified by ICP and SDE are connected. The X-ray diffractometer worked with Co kA radiation, 30 mA current and 30kV voltage and the common configuration (θ/2θ). The angle calculated was 30º until 100º with a step of 0.02º. For identify the main phases it was used the software *Match v.1.10a* with database Powder Diffraction (PDF). The phases quantification generated by software Match is computed by Rietveld method.

2.2 Particle Size Distribution

Particle size analysis of the BOF dust was performed using an automatic sieving during fifteen minutes, available in mineral technology laboratory of UFRJ.

3 RESULTS AND DISCUSSION

3.1 Chemical Characterization

The results obtained by spectroscopy can be visualized in Table 2. It can be observed in the Table 2 that total Fe (64.99 wt.%) is the main component identified in BOF dust followed by calcium (31.99 wt.%).

Table 2. Composition of BOF dust.

Components	(mg/L)	%
P	0.51	0.24
Al	1.1	0.51
Fe	141	64.99
Ca	69.4	31.99
Si	4.7	2.17
Ti	0.23	0.11

According to Mendes(1), high concentration of Ca is due to the addition of calcite into basic oxygen furnace to control the basicity of the slag. The average value obtained in this study confirmed those reported by several authors(2-7) with a wide range of concentration varying from 40 to 65 wt%. On the other hand, Takano, C.(3)

identified around 8.70 wt.% of calcium oxide in BOF thick mud, a low value compared with that presented in Table 2. Although, Junca *et. al*[(8),] in his work, it was found 23wt.%, a fairly high value when compared with Takano C.[(3)]'s work .

In addition, another elements in lower concentration were detected as aluminum, 1,1wt.%, 0,51 wt% of phosphorus and 0,23wt.% of titanium.

Those elements in higher amount were detected by X-ray diffractometer as magnetite (Fe_3O_4), hematite (Fe_2O_3), quartz (SiO_2) and calcite ($CaCO_3$) as indicated in the spectra shown Figure 2.

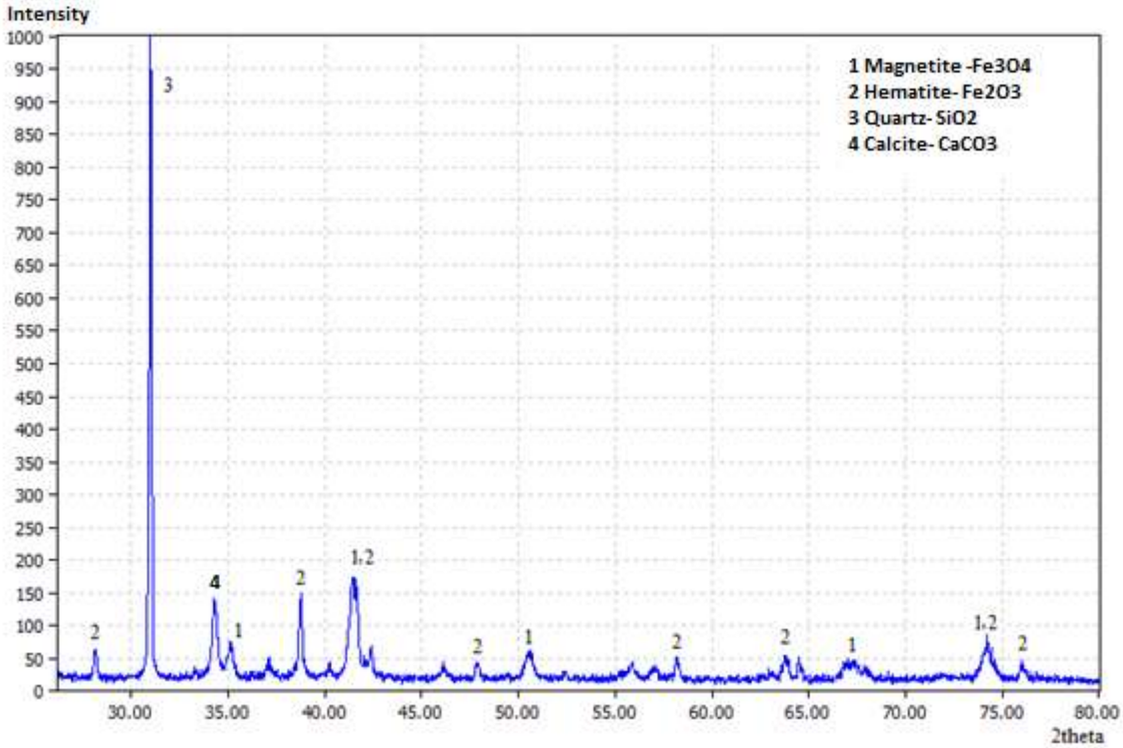
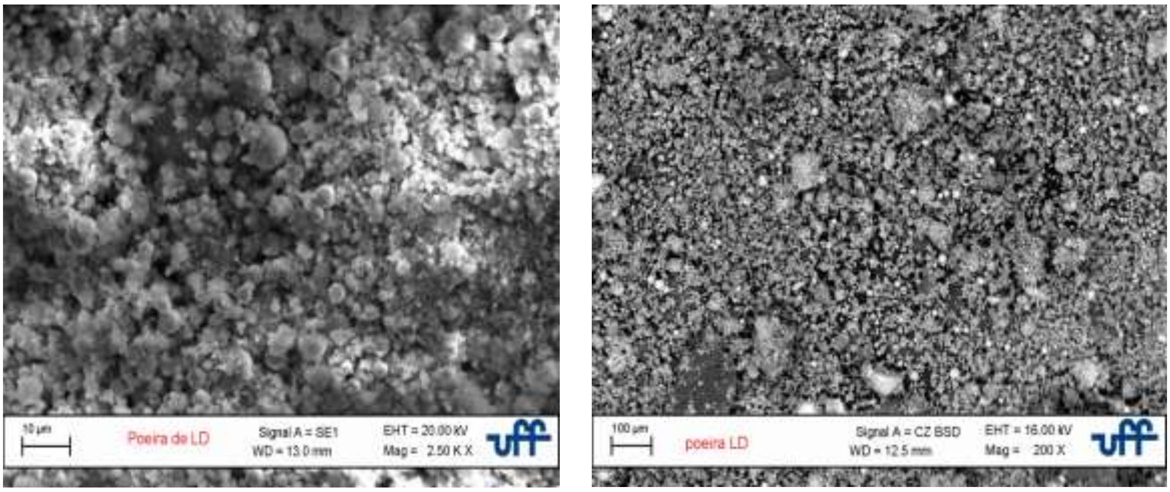


Figure 2. Spectra of BOF dust by X-ray diffraction.

In Figure 3, it is shown images acquired using SEM; in 3 (a), the image of an area of the sample obtained by secondary electrons (SE) detector, and in 3 (b) another region using the back-scattered electron detector (BSE).

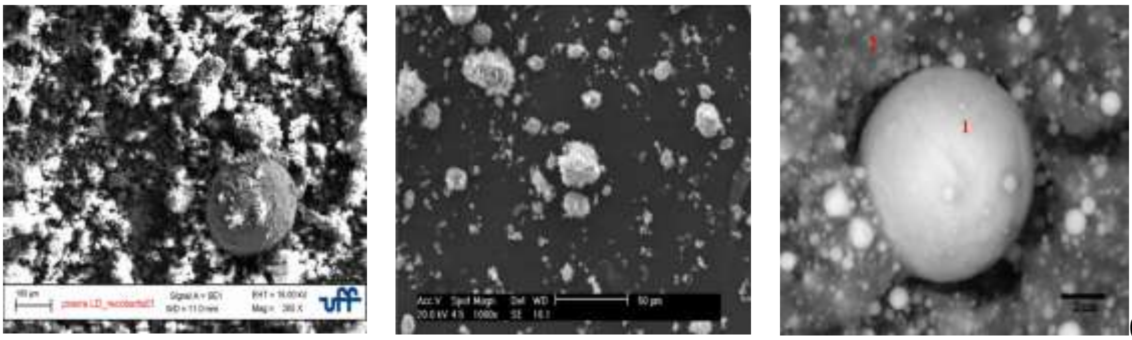


(a) (b)

Figure 3. Images of the sample of BOF dust acquired by (a) secondary electron detector and (b) back-scattered electron detector.

It is possible to visualize many spherical particles in the region analyzed, and this was observed as a pattern for all samples. A spot SDE was performed on these spherical particles and a high concentration of iron and oxygen was identified, as expected since the iron content slurry is obtained by solidification of liquid droplets during splash.

In Figure 4 is compared the images acquired in the current work with the pictures of BOF dust sample by Junca *et. al* (8) and EAF dust sample Machado, J.M.S.(9). As observed, their previous work also confirmed the presence of the same spherical particles present in the metallurgical processes dust.



(a) (b) (c)

Figure 4. a) spherical particle in BOF dust of the sample used in this current work, b) same particle found in another BOF dust sample and c) in EAF dust.

Figure 5 is the spectra obtained using spot SDE of the spherical particle shown in Figure 4(a).

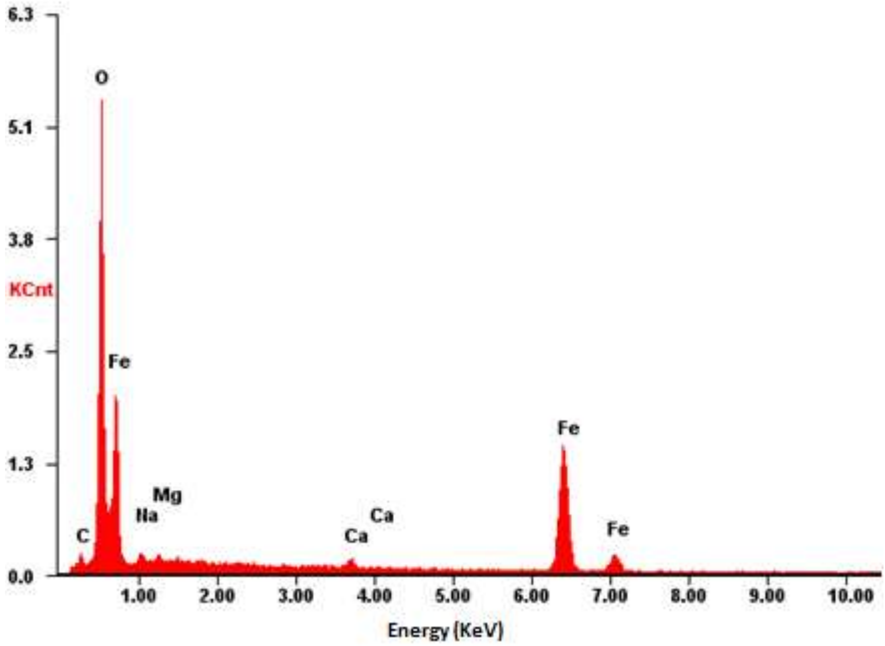


Figure 5. Spot spectra of the spherical particle obtained by SDE.

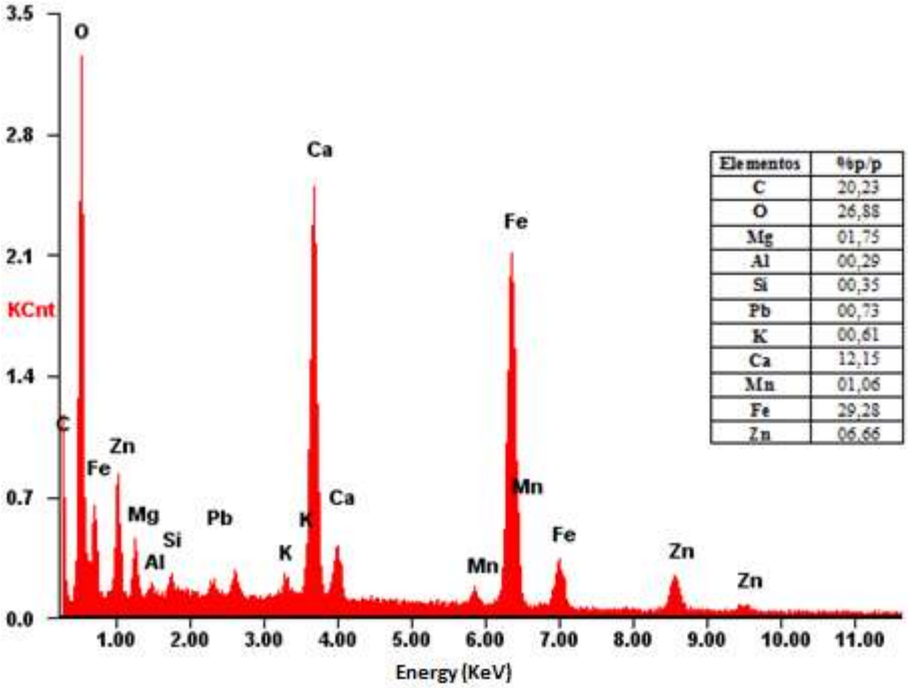
The presence of iron and oxygen was high, and in lower quantities, it was also detected elements such as magnesium, sodium, calcium and carbon. In the second column (Sample 01) in Table 3 it is displayed the analysis of average composition of five spherical particles of the sample studied in this work detected using SDE and in the third column (Sample 02) are the results for the same particles for EAF dust, according Machado, J. M.S.[(9)]'s work.

Table 3. Chemical composition of the BOF and EAF dusts.

Elements	Wt. % Sample 01	Wt. %Sample 02*
Iron	42.64	90.34
Oxygen	46.14	8.41
Sodium	1.59	-
Magnesium	0.99	-
Calcium	1.09	0.39
Silicon	-	0.25
Chromium	-	0.62
Carbon	7.56	-

*Footnotes: Machado, J. M.S., (2004)[(9)].

The SDE analysis performed by Machado, J. M.S.[(9)] detected 90,34 wt.% of iron and 8.41 wt.% of oxygen, which corresponds to magnetite, probably. Figure 6 is the result of the components obtained using SDE scanning performed in all area of sample identified in Figure 3 (a). The composition is shown in the table presented in Figure 6.

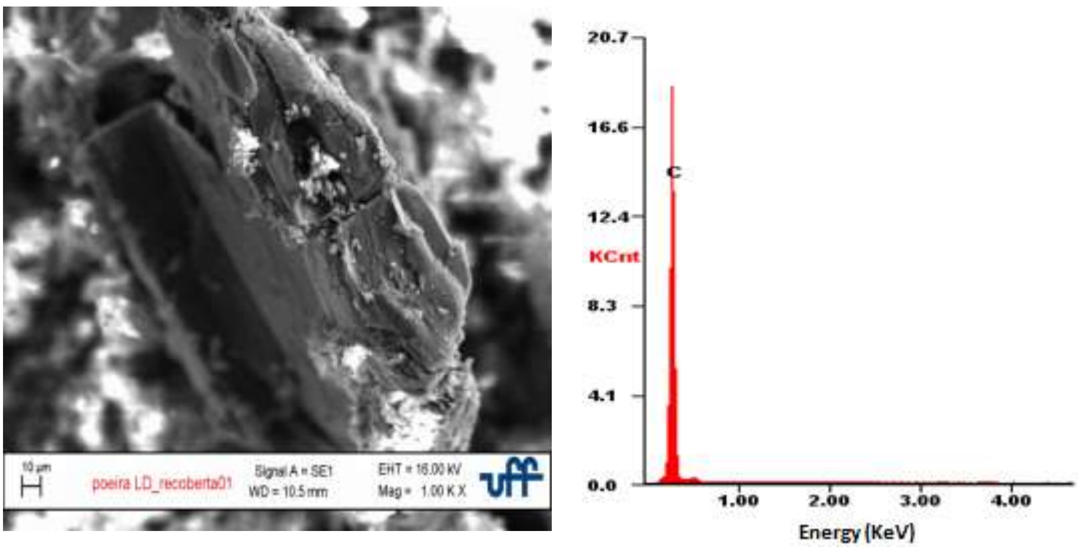


Elementos	%p/p
C	20,23
O	26,88
Mg	01,75
Al	00,29
Si	00,35
Pb	00,73
K	00,61
Ca	12,15
Mn	01,06
Fe	29,28
Zn	06,66

Figure 6. SDE Spectra of the BOF dust.

It was observed the presence of 6.66 wt.% of zinc, and others elements as Fe, Ca, Mn, Pb, Mg, usually found in dust of EAF and BOF(10,11).

In addition, a high concentration of carbon was detected, 20.23 wt.%. Figure 7(a) is the image of a particle in the sample commonly cognized. Figure 7(b) is the spot SDE, which confirmed that this particles is composed of carbon.



(a) (b)

Figure 7. a) Image of the particle obtained in SEM and b) respective spot scanning by SDE.

It was carried out a series of similar analysis on other areas and the average value of iron concentration found was 62wt.%.

3.2 Size particles distribution

Table 4 is the result of the mass retained in each sieve used in this work (0.15 mm until 0.0053 mm).

Table 4. Size particles distibution of the BOF dust.

Sieve opening (mm)	**Mass retained (g)**	**%**
0.15	8.47	5.69%
0.106	23.37	15.70%
0.075	15.19	10.21%
0.053	12.84	8.63%
< 0.053	88.97	59.78%
Total	148.84	100.00%

It can be seen that particle size distribution is situated in the range of 0.053 to 0.15 mm, with 59.78% smaller than 0.053 mm. The particle distribution is very fine and agglomeration process using nucleants particles is demanded in order to use this fines as raw materials for steelmaking process or reduction in self-reducing facilities(12).

4 CONCLUSION

In this work it was carried out the dust characterization of BOF converter using ICP, x-ray, SDE particles distributions and images obtained by SEM. The chemical analysis was performed by ICP spectrometer and 65 wt% of iron was detected with large amount of calcium, 32wt.%. The results of X-ray diffraction indicated that the major phase were magnetite (Fe_3O_4), hematite (Fe_2O_3), quartz (SiO_2) and calcite ($CaCO_3$). Chemical analysis by SDE allowed to confirm the large amount of iron present in the sample, showing an average percentage of 62% for different regions of the samples. Both analysis, X-ray and SDE, were satisfactory to recognize and quantify the constituents and phases. The images obtained by SEM allowed visualizing the particle morphologies found in the dust. The spot scanning by SDE performed together with the corresponding image confirmed the spherical geometry of the iron oxide present in the sample. The distribution of the size particles indicated that the size is in a range of 0.053 to 0.15 mm. The results obtained in this work were confirmed a detailed using several complementary techniques. The fully understanding of the characteristics of the particles and its agglomerates contributed to improve the use of self-reducing agglomerates in the reduction processes and also recycling into BOF or EAF processes.

REFERENCES

1. MENDES, J.J. Influência da adição da lama fina de aciaria a oxigênio nas características físicas e microestruturais de pelotas queimadas de minério de ferro (Master. Dissertation, Universidade Federal de Ouro Preto, 2009), 20.

2. KELEBEK, S.; YÖRÜK, S.; DAVIS, B. Characterization of basic oxygen furnace dust and zinc removal by acid leaching. Minerals Engineering, v.17, n.2, p.285–291, 2004.

3. TAKANO, C.; CAPOCCHI, J.D.T.; NASCIMENTO, R.C.; MOURÃO, M.B.; LENZ, G.; SANTOS, D.M. A reciclagem de resíduos siderúrgicos sólidos. In: SEMINÁRIO NACIONAL SOBRE REUSO/RECICLAGEM DE RESÍDUOS SÓLIDOS INDUSTRIAIS. Anais... São Paulo, 2000, p. 1-13. Ref. 13.

4 HAY,M.; RANKIN, W.J. Recovery of iron and zinc from blast furnace and basic oxygen furnace dusts: A thermodynamic evaluation. Minerals Engineering, v.7, n.8, p. 985-1001, 1994.

5. SCHEELE, J. V.; JOHANSSON, M. OXYFINES a new technology for in-plant recycling of dust and sludge in metal production industries, Recycling and waste treatment in mineral and metal processing. Technical and economic aspects, v. l, n.1, p. 109-118, 2002.

6. GRILLO, F. F. Recuperação do Zn e Fe da poeira de aciaria elétrica proveniente da produção de aço carbono. Dissertação, (Master. Dissertation, Instituto Federal do Espírito Santo, 2011).

7. YI, C. Experimental Research on Reducing the Dust of BOF in CO_2 and O_2 Mixed Blowing Steelmaking Process. ISIJ International, v.49, n.11, p.1694–1699, 2009.

8. JUNCA, E.; OLIVEIRA, J.R.; ESPINOSA, D.C.R; TENÓRIO, J.A.S. Characterization of dust generated in the bof converter. Minerals, metals and materials. In: TMS 2012 Annual Meeting & Exhibition, 2012, Orlando. TMS 2012 Proceedings, 2012. p. 221-227.

9. MACHADO, J.M.S. Estudo de Caracterização e avaliação da influencia do tempo na redução carbotermica do pó de aciaria elétrica. 2004, 108f. Dissertação (Master. Dissertation)- Universidade Federal do Rio Grande do Sul/UFRGS, Porto Alegre.

10. SAMMUT, M.L. Determination of zinc speciation in basic oxygen furnace flying dust by chemical extractions and X-ray spectroscopy. Chemosphere, v.70, p.1945–1951, 2008.

11 DAS, B. An overview of utilization of slag and sludge from steel industries. Resources. Conservation and Recycling, v.50, n.1, p.40–57, 2007.

12. MIKHAIL, S. A.; TURCOTTE, A. M. Thermal reduction of steel-making secondary materials I. Basic-oxygen-furnace dust. Thermochimica Acta, v.311, n. (1-2), p.113-119, 1998.