EFFECT OF CHARCOAL PHYSICAL PARAMETERS ON THE BLAST FURNACE POWDER INJECTION[1]

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Abstract

Brazil produces close to 35 % of hot metal directly from charcoal blast furnaces with low internal volume < 300 m3. This production generates waste, charcoal fines that can be used directly into Powder charcoal injection system. The main point of this paper is to study the behavior of this powder injected into the tuyeres of blast furnaces. It was used a simulator, considering the conditions into the tuyeres. In this context, physical characteristics like porosity, grain size distribution, and specific surface were correlated with the combustion index and charcoal injection rate. It was concluded that physical parameters are not limiting to higher charcoal injection rate, when the values are in the values supported by authors, it was concluded that the charcoal grain size can be increased till 0,162mm without problems to its combustion.

Key words: Charcoal; Powder coal injection; Grain size distribution

Resumo

O Brasil produz cerca de 35% do ferro gusa através de altos-fornos a carvão vegetal de pequeno porte (volume útil < 300m^3), gerando com isto resíduo, entre eles carvão vegetal fino (moinha). Este artigo estuda o reaproveitamento da moinha usada em ICP (Injeção de Carvão Pulverizado). O foco principal é o comportamento do carvão vegetal pulverizado injetado, através das ventaneiras, na zona de combustão destes altos-fornos. Utilizou-se para isto um equipamento de simulação, levando em consideração as peculiaridades destes reatores. Dentro deste contexto, características físicas como porosidade, granulometria e superfície específica são correlacionadas com índice de combustão e taxa de injeção. Concluiu-se que parâmetros físicos não são limitantes ao aumento da taxa de injeção, dentro da faixa estabelecida como ideal por vários autores. Aumentos na granulometria podem ser favoráveis sob o ponto de vista econômico para a prática de injeção de carvão vegetal em pequenos altos-fornos.

Palavras-chave: Carvão vegetal; Injeção de carvão pulverizado; Granulometria

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1 INTRODUCTION

This article was taken from a master's dissertation, defended by one of the authors recently in REDEMAT. The goal of this work is to stimulate independent producers of pig iron companies that do not have the technology of injection of pulverized coal in their blast furnaces and help to increase the development of those who are already practicing it, reaching higher competitiveness in the global market.

In Brazil the pig iron is produced by two routes, the blast furnace of coke and charcoal. In the case of charcoal, it can be divided into integrated plants, which produce steel as a final product, and the non-integrated that produce pig iron. In this second case, they are called independent producers of pig iron. Table 1 shows the distribution of iron production in the three sectors in the last 5 years. In Brazil, there is a direct reduction unit, which produces sponge iron which normally can be used in electric steelworks, replacing part of the scrap in them.

Table 1 – Total production of pig-iron in Brazil (Unit: Millions of tons).

Year	Charcoal		Coke	Total
	Integrated Plants	Independent Producers	Integrated Plants	
2002	1,29	6,75	21,59	29,64
2003	1,34	8,10	22,56	32,01
2004	1,44	10,08	23,22	34,76
2005	1,64	9,77	22,46	33,88
2006	1,70	9,46	21,27	32,45

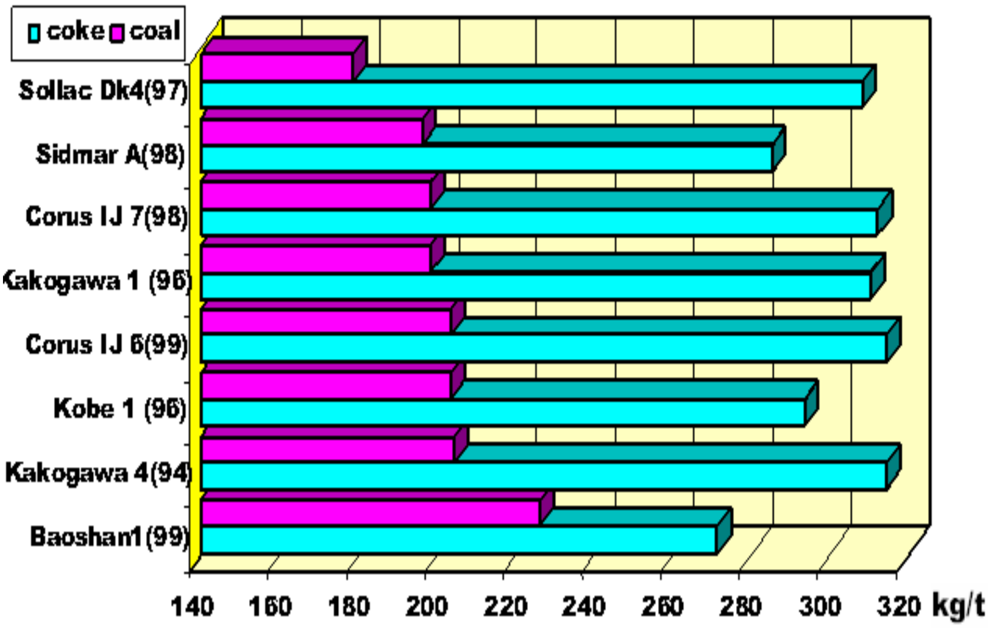
About these independent producers of pig iron, most of them do not have PCI (pulverized Coal injection) in their blast furnaces as can be seen in Table 2.

Industrial data shows that the injection of pulverized coal in small blast furnaces with charcoal is close to 80kg / ton of pig-iron while in the world it is practiced values over 150kg /(ton of pig-iron)[(1)] (Figure 1). Therefore, there is a huge gap between the independent sector of pig iron (SGA) and what is practiced in the world to make the application of this technology or technique economically viable for this sector so important for the country.

Table 2 - Small Blast Charcoal furnaces plant in Brazil with PCI, 2007[1]

	Total of Business	Total of BF	Total of Business with PCI	Total of BF with PCI
Quantity	83	153	8	22

[1] Table formed with data provided by Clyde Materials Handling, 2007 and the site of the Sindicato da Indústria do Ferro no Estado de Minas Gerais (SINDIFER), eletronic address http://www.sindifer.com.br/Anuario_2007.html, in day 15/01/2007.



[coke; coal]

Figure 1 - Rates of injection of coal in some blast furnaces with coke. [1]

The grinding of coal to injection in blast furnace today presents one of the biggest costs of the operations at the PCI. Some authors have the concept that the use of pulverized coal injection should have the size from 80% below 200 mesh.[1] One of the fundamental principles of the PCI is that coal injected must be burned in the area of combustion (raceway). However, when its burn does not happen completely, problems occur, as a reduction of permeability, because the pulverized coal form a layer around the area of combustion (bird's nest) or accommodate in the interstice of the of the blast furnace burden.[2] Figure 2 illustrates this phenomenon.

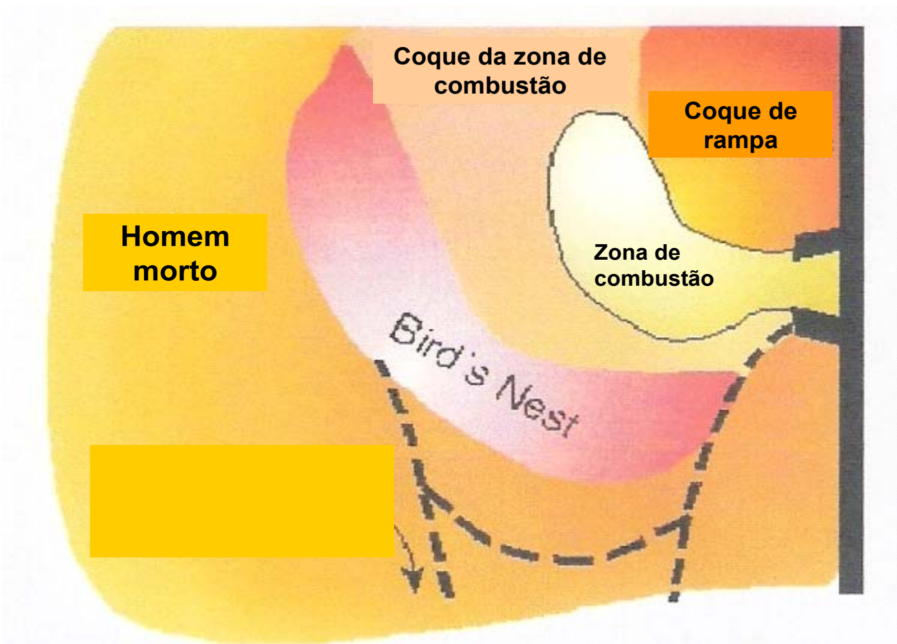


Figure 2 – Representative model of a structure of coke in the level of tuyere of the blast furnace [2]

The burning of pulverized coal in the area of combustion is linked to two important factors; amount of oxygen available for the reaction of combustion and size. In this case, Figure 3 shows the dependence of the diameter of the particle with the speed of combustion, that is, the smaller the value of diameter is the bigger burning rate is (3). This is important, therefore, the time the particle of coal stay in the "raceway" varies from 20ms to 50ms.[1]

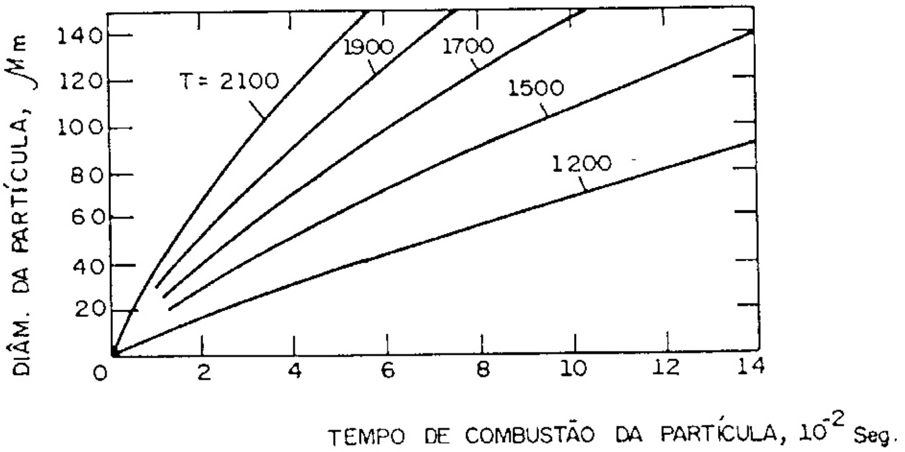


Figure 3 -Influence of the diameter of the particle of coal pulverized on the total time of combustion for different temperatures of the gas phase.[3]

Properties as porosity and specific surface area can contribute to the efficiency of pulverized coal combustion, that is, increase the combustion rate. This is due to greater contact between oxygen and charcoal particle increasing the kinetics of the reaction of combustion.[3]

2 MATERIAL AND METHODS

The samples were taken after the grinding, drying and mixtures system of coal plants of the PCI, that is, did not take account of its origin. The regulation NBR6923 (Charcoal - Sampling and preparation of sample, from 1981) of ABNT (Brazilian Association of Technical Standards) was used to conduct the sampling. They were divided and separated in the amount of 150g per sample. Samples were identified, regarding their immediate chemical analysis (C1, C2 and C3), size (G1, G2, G3), moisture (U1, U2 and U3) and source (AP). They were stored in plastic containers properly prepared and identified to receive them.
To determine the average size, the regulation used is the ABNT NBR7402 (Charcoal - Analysis granules, 1982). And to determine the immediate analysis on a dry basis was used the regulation ABNT NBR8112 (Charcoal - Analysis immediate, 1986).
The use of BET (Brunauer, Emmet & Teller-- the name derives from the initials of the names of scientists that developed it), which is a method to determine the porosity of the grain, provided the determination of various physical properties. Highlight for, specific surface area, total volume of pores and volume of micropores of the samples.
The analysis of the burn index was through a combustion simulator (UHTS), which simulates the peculiar conditions of the combustion zone. The blast temperature was maintained constant at 800° C and the temperature of gas in the area of high temperature was monitored at 1200° C. The injection rate varied of 60kg / (t of pig iron), 100kg / (t of pig iron) and 120kg / (t of pig iron). The ICP simulator can be seen at Figure 4. The equipment and how the combustion rate is calculated are shown in other publication.[5]

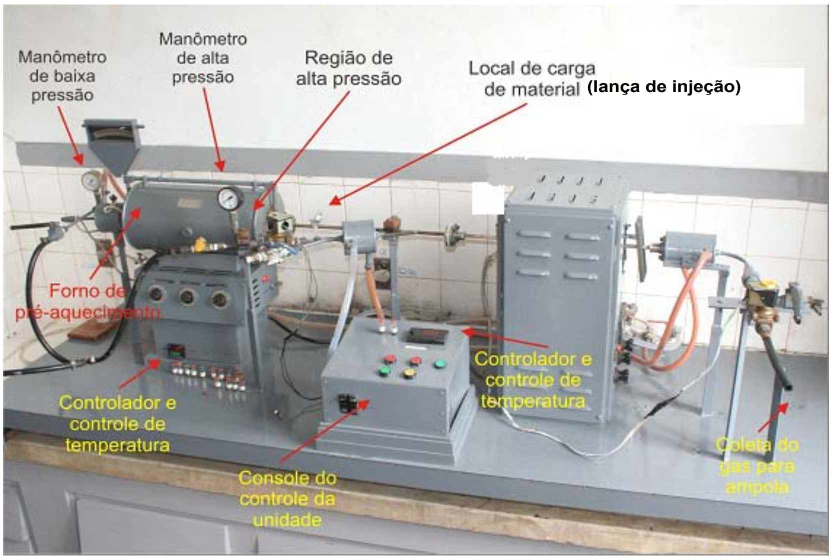


Figure 4 – Equipment used to simulate the injection of pulverized coal in blast furnace; available at the Laboratory of Iron and Steelmaking, Escola de Minas-UFOP.

3 RESULTS AND DISCUSSION

The chemical and size results of the samples are showed in Table 3.

Table 3– Representation of chemical analysis and size of characterized charcoal

Samples	Immediate Analysis; dry basis				Elementary Analysis				Average size(mm)
	Cf (%)	TU (%)	MV (%)	CZ (%)	C (%)	H (%)	N (%)	O (%)	
C1	54,8	1,4	24,2	21,0					0,070
C2	59.6	1,4	24.6	15.8					0,072
C3	65.3	1,4	24.1	10.6					0,068
U1	59.6	1.1	24.6	15.8					0,070
U2	59.6	2.9	24.6	15.8					0,072
U3	59.6	4.8	24.6	15.8					0,070
G1	60,1	1,5	24,4	15,5					0,070
G2	59,8	1,5	24,3	15,9					0,119
G3	60,9	1,5	24,4	14,7					0,162
AP	60,1	1,6	24,2	15,7	66,67	2,54	0,81	29,98	0,073

The results of BET tests are showed in Table 4.

Table 4 --Parameters' Results of porosity and real density of charcoal

Sample	**Specific surface**	**Pores' Total Volume**	**Micropores' Volume * (θ_m<2ηm)**	**Micropores' Área ***	**Pores' Average Diameter**	**Maximum Size of Pores**	**Density**
Unit	**m^2/g**	**$10^{-2}cm^3/g$**	**$x10^{-3}cm^3/g$**	**m^2/g**	**Å**	**Å**	**g/cm^3**
C1	1,861	0,5804	0,7991	2,262	120,48	2918,6	1,512
C2	1,729	0,6945	0,7995	2,264	160,07	1342,8	1,504
G1	1,367	0,1143	0,7453	2,110	330,44	1795,4	1,597
G3	2,171	1,086	1,0119	2,885	200,00	1466,8	1,539
AP	2,442	1,102	1,057	2,993	180,05	2278,1	1,555

** Micropore classification is made by pores' diameter (θ_m < 2ηm) and macropores' diameter (θ_m > 50ηm) according to IUPAC (International Union of Pure and Applied Chemistry).*

Table 5 shows the results obtained in the combustion simulator.

Table 5 – Test of combustion's results obtained in UHTS

Sample	Origin (analysis)	Injection Rate (kg/t pig iron)	Combustion index (IC)
C2	59,6% Cf	60	0,930
		100	0,861
		120	0,809
G1	70 μm	60	0,950
		100	0,884
		120	0,816
G2	119 μm	60	0,949
		100	0,882
		120	0,820
G3	162 μm	60	0,946
		100	0,872
		120	0,806
AP	73 μm	60	0,952
		100	0,882
		120	0,819

Figures 5 to 7 represent the relation of coal´s parameters examined in the BET, with the combustibility´s index and injection´s rate, keeping the fixed carbon and size constant. It was observed that there weren´t significant variations of IC and TIP with those characteristic charcoal parameters.

Figure 5 represents the relation between total volume of pores with the combustion´s rate, showing a slight variation of IC with the variations of the volumes of pores. In this case it is correct to say that the pores didn't have great influence on improving the combustibility. This can be found in the figures 6 and 7. It's important to note that in Figure 7 there is the ratio of specific surface versus the combustion´s index; in this case, as the size is constant, an increasing of specific surface is related to the increasing in porosity.

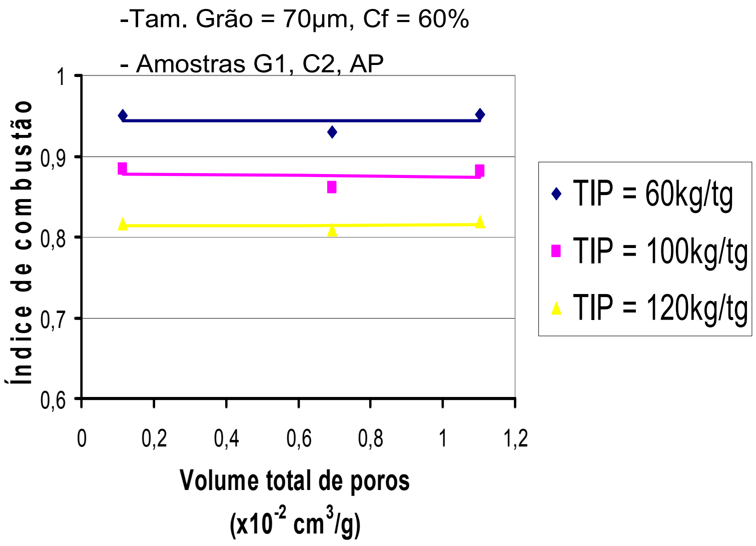


Figure 5 – The relationship between total volume of pores (X axis) and combustion index (Y axis), varying the injection rate (kg/t pig iron).

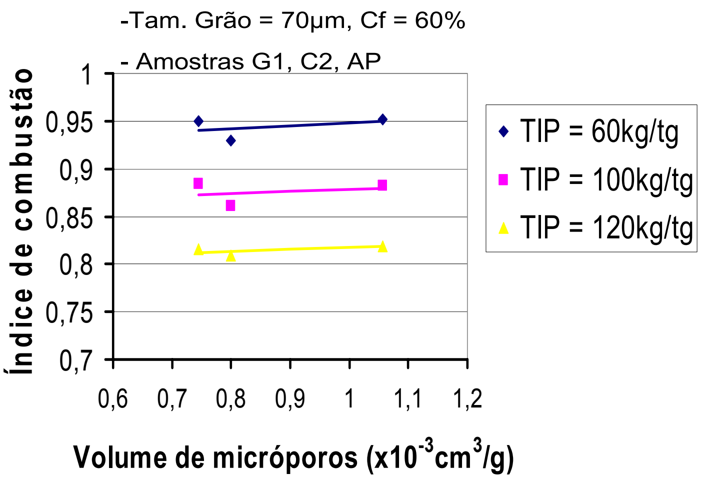


Figure 6 – Relationship between micropores' volume (X axis) and combustion index (Y axis), varying the injection rate (kg/t pig iron)

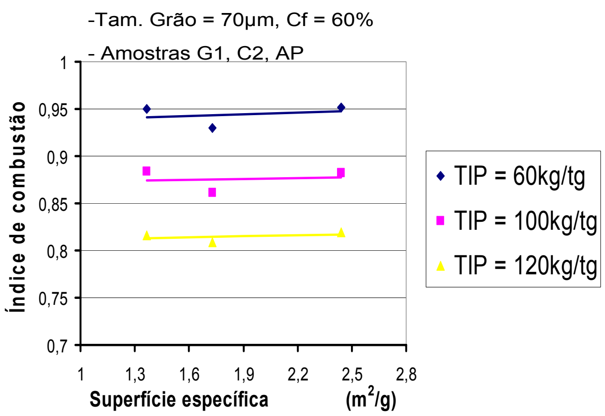


Figure 7 – The relationship between specific surface (X axis) and combustion index (Y axis), varying the injection rate.

In the case of Figure 8, can be observed that an increase in the size meant a slight decrease in the combustion´s rate, for the same injection rate of pulverized coal. Economically, this can be sensitive during the grinding of charcoal, because changing the size from 162 μm to 70 μm is very expensive and without improvement of combustibility. It shows that working with average size above the established by many authors (80% <74 μ m) may be viable, under the conditions obtained in this contribution, deserving a more detailed specific evaluation for each case.

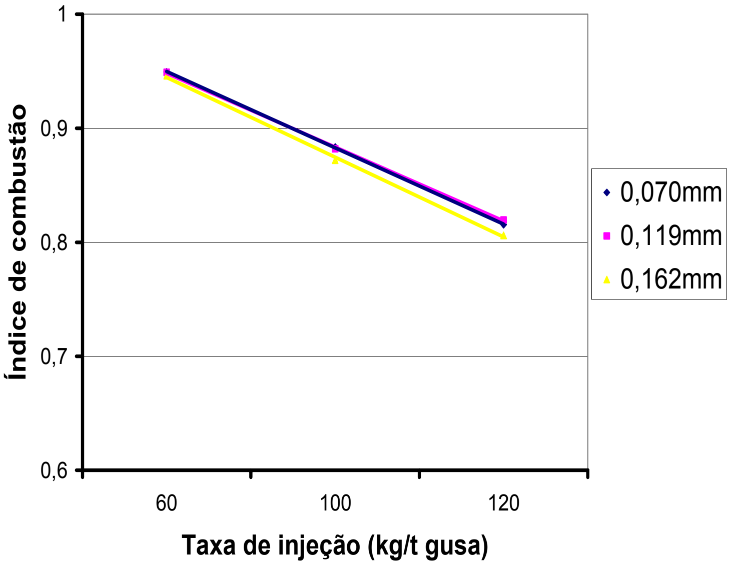


Figure 8 - The relationship between injection rate (X axis) and combustion index (Y axis) for different particle size.

It is clear therefore that the distinctive effect that influences directly into the combustion index is related to the chemical reaction (or relation O / C) instead the physical factors, demonstrating that the coal grinding plant doesn't need to be restricted to values defined by close industrial practice (80% <200 mesh), certainly resulting in raising costs of grinding and without gains in the combustibility of charcoal in the raceway. Again, an observation mentioned above, that is always important to evaluate the blast furnace and pulverized system plant in order to be able to obtain better technical and economic results of the system.

5 CONCLUSION

Preliminary results using the equipments of the Steelmaking Laboratory of the Escola de Minas-UFOP suggest:

- It is possible to inject up to 120 kg/(ton of pig iron) in small charcoal blast furnaces, with particle size up to 162 μm.
- There is no significant loss in terms of combustitibility when changing the size of charcoal from 70 to 162 μ m.
- Marginal gains with the adoption of the technique of pulverized coal injection plant with larger size may be obtained in small blast furnaces: which are reduction in the cost of grinding, raising the pulverized coal injection rate, without any charge in the combustion zone , besides having higher productivity for milling of charcoal.
- The chemical phenomena are responsible for the proposed changes in the size of charcoal injected into charcoal blast furnaces, and have in their physical characteristics a convincing explanation about the combustibility of charcoal.

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REFERENCES

1 Assis, P. S. et alli. *Curso de injeção de materiais pulverizados em altos-fornos*. Livro publicado pela ABM, Associação Brasileira de Metalurgia e Materiais, 2006, 292p.
2 Stainlay, R., Bennett, P. *PCI Coal – Status and Forecast*. 1° International Meeting on Ironmaking – ABM - 24 a 26 de setembro de 2001, Belo Horizonte - M.G. V. 1, p.24-34.
3 Braga, R. N. B. et alli. *Carvão Vegetal, Produção, Propriedades e Aplicações na Siderurgia*. Livro publicado pela ABM, Associação Brasileira de Metalurgia e Materiais, 1992, 320p.
4 Castro, L. F. A. *The Mini Blast Furnace – A Challenge for a New Ironmaking*. 1° International Meeting on Ironmaking – ABM - 24 a 26 de setembro de 2001, Belo Horizonte-M.G. V. 1, p. 485 – 494.
5 Assis, P. S., Martins, W. B., Vieira, C. B. *Avanços na Injeção de Carvão Pulverizado para a sua Aplicação em Altos-Fornos*. REM, Revista Escola de Minas, v. 56, n. 4, Ouro Preto Oct./Dec. 2003, 9p.
6 Barroso, R. C., Peres, A. E. C., Montenegro, L. C. M., Galery, R. *Caracterização Tecnológica dos Finos de Carvão Vegetal*. XXXV Seminário e Redução de Minério de Ferro e Matérias-primas e VI Simpósio Brasileiro de Minério de Ferro, 30 de agosto a 2 de setembro de 2005, Florianópolis-SC. Anais V. 1, p. 284 - 293.