EVALUATION OF THE USE OF MIXTURES OF CHARCOAL AND RICE RIND FOR ITS INJECTION IN THE TUYERES OF BLAST FURNACES [1]

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Abstract

Trends in the steelmaking industry indicate a need to substitute the use of charcoal in the production of the pig-iron for new energy sources in current blast furnace processes. This article studies ICP (Injection of powder charcoal) with the incorporation of the rice rind to the fine of charcoal used in the pig-iron production. The simulation equipment was used to consider the peculiarities of these reactors. Within this context, the effects of the mixture of charcoal and rice rind are correlated with the combustion rate and the injection rate. In conclusion, the injection rates have values that are close to the combustion rates. Therefore, the product is available even if the injection rate is high.

Key words: Charcoal; Charcoal injection; Blast furnace; Rice husk.

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1 INTRODUCTION

1.1 Pig Iron Production

There are several iron and steelmaking businesses in Brazil using charcoal blast furnace in integrated steel plants and pig-iron production, as showed on Table 1. Over many decades the steelmaking sector has been developed, as a result of increased production and higher operational stability of the blast furnaces. Among these improvements, the increased production demands the implementation of charcoal injection process (ICP) in the tuyeres of the blast furnace.
In this context, the mixture of charcoal and rice rind was studied in different percentages with the goal to have a more positive process from a technical and economical perspective.

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

Year	Charcoal		Coke	Total
	Integrated Plants	Independet Productors	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

Source at website:
http://www.showsite.com.br/silviminas/html/index.asp?Metodo=ExibirLista&Grupo=4%20&SubGrupo=32
Sindicato da Indústria do Ferro no Estado de Minas Gerais (SINDIFER), at 01/15/2008.

1.2 Injection of Pulverized Coal (ICP)

The engineering of pulverized coal injection has been practiced all over the world. The injection of materials in the blast furnaces decreases the cost for pig-iron production, by substituting coke which is charging on top of the furnace. There are many materials that can be injected including: teer, natural gas, wastes containing high percentages of carbon, injected ore fines, flux and plastic, and other materials. The practice of injecting materials can result in cost reduction, hot metal quality improvements and the environmental improvements.
Also, there are several situations that need to be considered when injecting coal and other materials. One example is the high flame temperature that provides a good viscosity to pig-iron and slag. So there can be a thermal improvement without disturbing the blast furnace permeability. The three main factors that affect combustion rate are particle size, volatile content and ash content [1].

1.3 Rice Rind [(2)]

Since ancient times, rice has been the main cereal for half the world's population. About 90% of all rice is produced and consumed on the Asian continent. Nowadays, China contributes approximately 37% of the world production, India 20% and Latin America 3.5%.

In Brazil there are two ways of rice production – Sequeiro – used in Goiás, Mato Grosso do Sul and São Paulo, these states have 70% of the production area. And – Irrigado – on Santa Catarina and Rio Grande do Sul are states that have the remaining 30%. Also, 40% of all the rice produced in Brazil come from the Rio Grande do Sul state. The rice refinement consists on grain drying, cleaning, husking and polishing. As told by the "Instituto Riograndense do Arroz," the conventional techniques of rice refinement give industrial yield represented by the numbers: 100 kg of rice generate 68kg of grain (50kg of intact grains and 18kg of cracked grains),10kg of powder rice and 22kg of crust.
Within each ton of rice produced, there is one ton of straw and 220kg of crust. The actual (2007) annual production generation in Brazil is 10.9 million tons of straw and 2.4 million tons of crust.
While the rice is growing, the crust is formed as a protection for the grain. The crusts are removed in the refining process because its fibers do not have nutritional value and cannot be used for human or animal supply and because of the SiO_2. The crust does not have commercial value.
The rice crust is composed basically by four layers:

1) Outside epidermis, covered by a thick layer of siliceous cells;
2) Hipodermis fiber, with a lignin cap;
3) Sponge Cell parenchima,;
4) Inside epidermis.

The silica can be better found in the outside epidermis.

1.3.1 Composition[3]

Rice rind contains 11,4% ash content which has 80-90% of SiO_2, 5% of K_2O, 4% of P_2O_5, 1-2% of CaO and amounts of Mg, Fe and Na. The main organic components of rice rind are cellulose, hemicellulose and the lignina.

1.3.2 Power calorific inferior (PCI)

The PCI is the amount of free energy in the complete combustion of a unit of mass of fuel [4]. The PCI is one of the parameters important to be considered for the quality of fuel, showed in Table 2. The rice rind presents characteristics, such as: high heating value (approximately 16,3 MJ/kg), a content of 74% of volatile materials and 12.8% of leached ashes. These characteristics indicate that the rice rind can be a good fuel. Once the technology of conversion exists and the rice rind is abundant in the South region of Brazil, the generation of energy through the burning of this material can be a practical and correct alternative from an environmental point of view. Also, all of the CO_2 produced in the burning process returns to the cycle of the biosphere.

Table 2 - PCI in some fuels (kcal/kg)

Fuel	PCI
Bagasse of sugar cane (20% moisture)	3.200
Bagasse of sugar cane (50% moisture)	1.800
Mineral coal - Cambuí/PR	6.200
Mineral coal - Charqueadas/RS	3.100
Mineral coal - Mine of lion RS	4.200
Mineral coal - Tubarão SC	4.500
Charcoal	7.500
Rice rind (12% water)	**3.300**
Metallurgical coke	7.200

Source: Aalborg Industries S.A

1.4 Steelmaking, Charcoal and Rice Rind

In the production of the pig-iron in the blast furnace, the charcoal fulfills four functions: a thermal agent that supplies necessary heat to the process; a chemical agent for removing oxygen of iron oxides; a physical agent and a carburizing agent for hot metal. During the burning of the charcoal, the energy losses are very high. Therefore, "the sum of the energy within the chemical reaction plus the heat absorbed for the pig-iron and the slag is less than the energy content of the gases set free in the process." The process of reduction and fusing of the iron effectively uses 40% of the energy given by the charcoal. The final products of this process are pig-iron and slag. This industrial sector has suffered very few changes in the fundamentals production basis over the past decades (5).

The energy inefficiency of this productive process is still increased by the fact that the pig-iron production is marked by low energy efficiency and involves the use and dispersion of enormous amounts of substance and energy. The technology used for production does not differ much between the plants. The significant difference is that some pig iron producers possess a system of powder charcoal injection in the blast furnaces. Remembering that the majority of the blast furnace process (2007, close to 85 %) does not possess this system of pulverized charcoal injection.

There is a need for incorporating new energy inputs in the pig iron production for this the rice rind which presents an interesting challenge to the iron industry. The rice rind possesses interesting characteristics like its composition, the economic feasibility, the availability of the product in the market, in addition to the fact that the rice rind can be obtained without significant disruption to the environment compared to the extraction of wood (for reforestation and destroying virgin forests) for the production of charcoal that requires a long cycle of at least two decades. In addition, the rice rind comes from a product that is commonly used in Brazil and all over the world.

The capital investment for a so long stated period sometimes can not be assimilated from the companies those produce only pig iron. This way this alternative can permit a reduction on the cost of pig iron by using a sustainable waste from the farmers.

2 MATERIAL AND METHODS

2.1 Sample Preparation

After the sample is milled and sieved, they were weighed and stored in glass containers without moisture with variable percentages of rice rind and charcoal, as it can be seen in Table 3. This table shows the weight for each group and the weight percentage for each material. For the last samples (50 mg), only the weight and percentage of coal are shown. The rice rind weighed 50 mg for each sample.

Table 3 – Mass and weight % prepared for all simulated mixtures

Coal		Rind		COAL		RIND		COAL	
%	mg	%	mg	%	mg	%	mg	%	mg
0	-	100	112	100	80	0	0	0	0
20	28	80	112	80	64	20	16	20	10
40	56	60	84	60	48	40	32	40	20
60	84	40	56	40	32	60	48	60	30
80	112	20	28	20	16	80	64	80	40
100	140	0	0	0	0	100	80	100	50

2.2 Milling Process

The milling was carried through a dry process in the laboratory of the Department of Minong Engineering – DEMIN of Escola de Minas – UFOP in a mill of balls with characteristics demonstrated in Table 4. For milling, it was necessary to divide the material into two identical millings in two stages. In the first one 300g of rice rind was placed in the mill and milled during two hours. In the following stage 300g was placed again in the mill and grinded for 8 more hours totaling 600 g in 10 hours of milling.

Table 4 - Characteristic of balls mills used

Parameter	Value
Size	20 cm x 20 cm
Balls	Mn Steel
Average Diameter of the Balls	1,5 pol = 3,81 cm
All Up Weight of the Balls	11,880 kg

2.3 Screening Process

The screening was made to get a separation of the material in two or more fractions, with particles of distinct sizes. For this contribution three screenings had been made- the dry one with a sequence of five bolters, cited in table 5, in the objective of if getting fewer particles than 200 mesh. In the first screening, without expressive results, the following was used: frequency of 45 Hz and a time of 10 minutes. No longer according to screening, one ball from a marble game was added in each bolter, same Table 5, and as the frequency is increased the to 55 Hz and the time is increased to 20 minutes there is a better efficiency of screening.

Table 5 - Opening of the Meshes and number of balls in each bolter

Bolters	1ª	2ª	3ª	4ª	5ª
Opening of the Meshes	48 mesh	65 mesh	100 mesh	140 mesh	200 mesh
Nº of marble game balls	14	5	4	4	4

This way, it can guaranteed that the grain size of rice rind was less than 200 #.

2.4 Charcoal

The samples were collected in a small furnace, before the grinding system and after the grinding system for powder charcoal injection. The norm NBR6923 of ABNT was used to get the samples. They were separated composing 150 g of sample. This sample was identified considering this immediate analysis, moisture and grain size distribution. For determining the grain size distribution ABNT NBR7402 Norm was used. By other side, the norm ABNT NBR8112 was used for immediate analysis.

2.5 Simulation of Combustion Process

Through a simulator equipment of the blast furnace raceway built at Escola de Minas - UFOP, the mixture between coal and rice rind was simulated in different rates and different percentages of charcoal. The Figure 1 shows the equipment used.

The simulator has a pre-heating furnace for heat supply of the oxygen used in the blast, and an electric furnace capable of operating at temperatures above 1300°C, characterizing the combustion zone.
As stated earlier, the gas used in the process is the pure oxygen stored in cylinders each of 13m^3, which are attached to the simulator through hoses properly designed for this purpose. Through a glass funnel the mixture is introduced in the opening called "s" so that after this procedure is closed so the material is not injected. The kilns are heated previously, at temperatures around 800°C for the pre-heating furnace and over 1200°C for the combustion furnace.

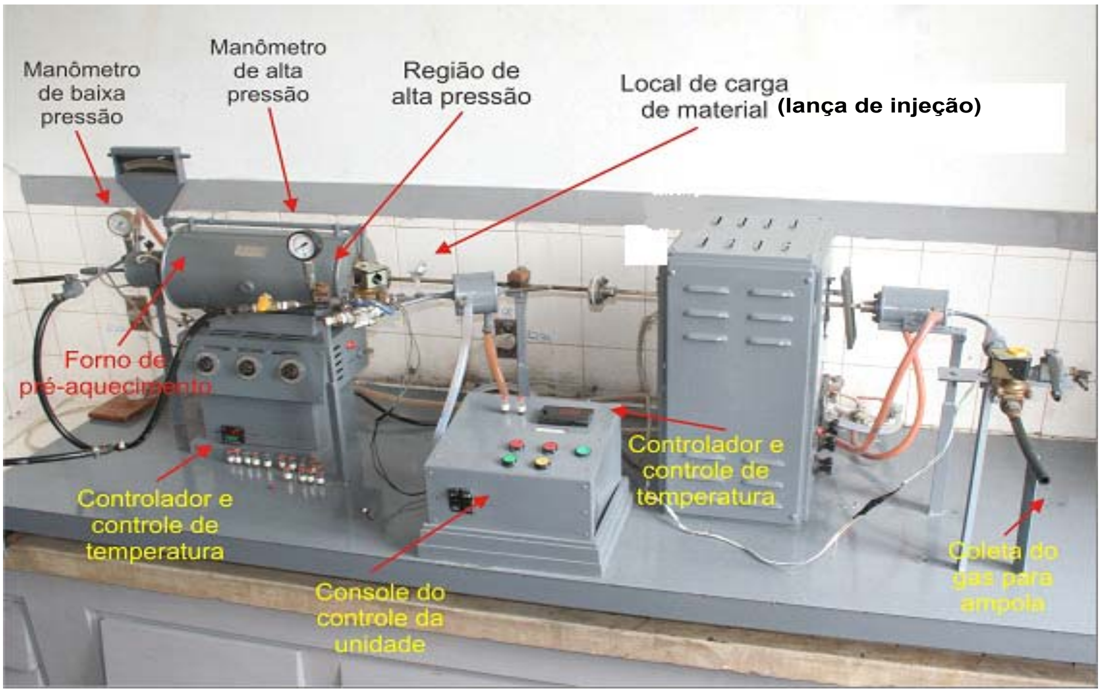

Figure 1 - Equipment used to simulate the injection of pulverized coal in blast furnace; available at the Iron and Steelmaking Laboratory at Escola de Minas.[6]

Opening the valve of the cylinder, part of the gas goes to the pre-heating furnace where it is heated up to the blast temperature, similar to what occurs in the blast furnace. The other part goes to the injection lance, to promote the drag of the pulverized material under the command of an electromagnetic valve.
The material dragged enters into contact with the gas coming from the pre-heating furnace and going together to the combustion furnace where the burning of materials happens. The gases resulting from this process are collected in ampoules, and then follow for a gas analyzer which also consists of a set of ampoules, containing the appropriate solutions for analysis of each type of gas, CO, CO_2 and O_2.
The gas analyzer (ORSAT) is a set of glass ampoules containing appropriate solutions needed for the analysis of gas. This system is interconnected by glass tubes through which the gas is forced to move thereby generating a solution separating the appropriate fractions of CO, CO_2 and O_2, the solutions used are copper chloride for CO, pirogalol for O_2 and potassium hydroxide for CO_2. Through a tube containing a saline solution and for the difference in level between it and the ampoules of solutions you can measure the percentage of each gas that composes the sample.
After analysis it is estimated the index of combustion using the formula:

$$TI = \{(\%CO + \%CO_2)*n_g/ [(m_a*\%C/1200000) - (k_1*n_g/100)]\}*100$$

observing that:
TI = combustion rate (%)
$\%CO, \%CO_2$ = percentages of the gases;
n_g = number of moles of the gas;
m_a = mass of the sample of carbon injected, in milligrams.
k_1 = constant determined for each material injected.

3 RESULTS AND DISCUSSIONS

Based on methodology, some samples of charcoal were prepared and afterwards analyzed. Table 6 shows the obtained results.

Table 6 – Obtained results for charcoal samples

Sample	Immediate analysis; dry base				Elementary analysis				Granulometry measured (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

For this research, AP was selected to be used in the experiments.
The results obtained from the samples related before can be summarized in the Table 7. In this table we had mixture of charcoal and rice rind in different proportions and rates. The results are a medium value of three calculated combustion rate based on the above equation.

Table 7 - Effects of the injection rate and rice rind mixture on the combustion rate

Charcoal + Rice rind				
Injection rate (kg/t hot metal)		50	80	140
Charcoal (Weight %)	**Rice rind (Weight %)**	**Combustion rate (%)**		
0	100	82	81,3	78
20	80	88,3	86,7	85,3
40	60	91,4	92,4	88,2
60	40	93,8	95,3	89,2
80	20	95,2	94,8	88,4
100	0	94,8	93,2	87

Based on the results taken from the experiments in the Table 6, two pictures can be shown. Figure 2 shows the relationship between the mixture of rice rind and charcoal under different injection rates. Based on this picture, it can be seen that by higher weight percentage of rice rind on the mixture, higher values of combustion rate can be obtained. This can be explained based on the mechanisms proposed by Assis.[1] The Figure 3 shows the effect of injection rate on the combustion rate by using 100% of charcoal and 100% of rice rind. Based on this graph, it can be seen that for all injection rate higher values of combustion rate is obtained by using only charcoal, but for higher values of injection rate, the difference between combustion rate of both fuels are less.

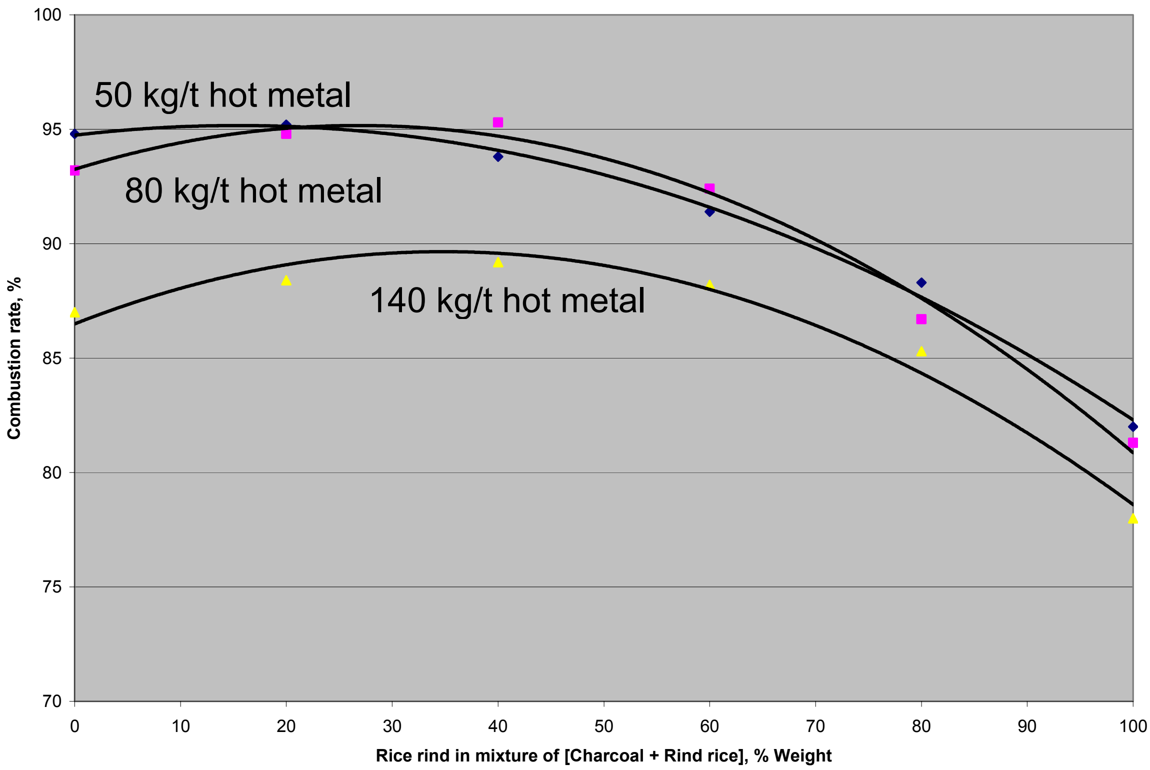

Figure 2 – Effect of mixture of rice rind and charcoal on the combustion rate by different values of injection rate

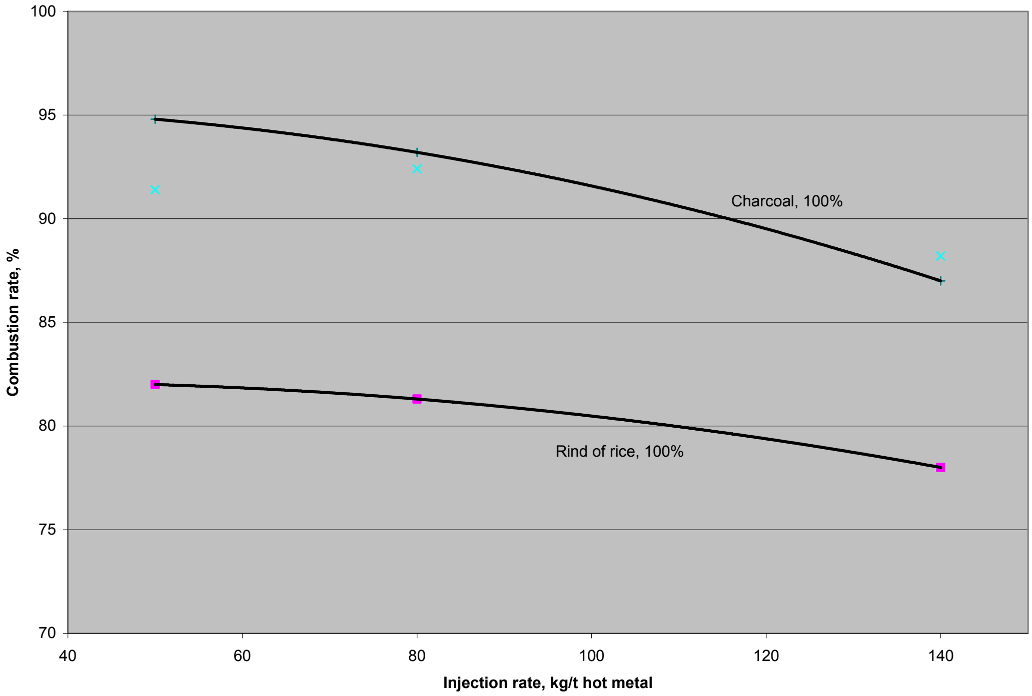

Figure 3 – Relationship between injection rate and combustion rate for charcoal and rice rind

4 CONCLUSIONS

Based on the conducted research, some conclusions can be drawn:
- Optimum combustion rate can be obtained when 30% of rice rind is added into a mixture of charcoal and this material.
- Higher values of combustion rates can be obtained when 100% of charcoal is used for injection. But when the injection rate is increased, then the difference between combustion the rates of both fuels is smaller.
- By practicing mixtures of fuels like rind of rice and charcoal. The combustion rate can be increased if it is compared with only one fuel.

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