DEVELOPMENT OF COMBUSTION AND ASH BEHAVIOR OF PULVERIZED COALS INJECTED IN ARCELORMITTAL TUBARÃO BLAST FURNACES[1]

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Abstract

One of the most relevant aspects for the success of the PCI technology is the appropriate choice of the coals to be injected. At ArcelorMittal Tubarão, coals are selected based mainly on their chemical analysis and price. It has been shown that these criteria are not enough to guarantee adequate performance of the blast furnaces where the coals are injected into. In the present work, two different coals that presented completely different performances when injected into blast furnaces have been characterized in terms of chemical and petrography analysis, reactivity in CO_2 and O_2 atmospheres and reactivity of the char in air. The behavior of the ash at high temperatures has been analyzed using X-ray diffraction and scanning electronic microscopy (SEM). The fusibility and the viscosity of the ash have also been determined. The results indicated that the behavior of the ash at high temperatures, particularly in terms of viscosity, plays a significant role in determining the performance of the coals in the blast furnace.

Key words: PCI; Ash viscosity; Blast furnace; Combustion.

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1 INTRODUCTION

The mineral coal is currently the main fuel injected in the large size blast furnaces. The consequences of the injection of pulverized coal in the coke blast furnace depend on several process variables which are controlled so as to allow high injection rates, thus reducing total coke consumption. The main factors affecting the performance of the coal injected in the blast furnace [(1)] can be summarized in three different aspects: coals properties, combustion conditions and the equipment used in the plants for grinding, transportation and injection of coal. Bringing these three aspects to the universe of the present study, one can say that the combustion conditions and the equipment used for injection are identical for the all the different coals injected at ArcelorMittal Tubarão, considering that the same blast furnace is used for the comparison, maintaining the other variables that could interfere in the process practically constant. Thus, it can be said that the major aspect that interferes in the process is mainly related to the properties of the coal being used.

Currently, the bigger part of the scientific studies is directed to the evaluation of the efficiency of coal combustion and energy purposes. In the specific case of pulverized coal injection, it is believed that combustion is not the only factor to be considered when analyzing the injection process from a broader view point. It is important to state that the more efficient the coal combustion is, the better its performance in the blast furnace will be. However, in operational practices it is noted that coals with similar reactivity have a different behavior in the process. Consequently, a more comprehensive study seems relevant so as to establish other characteristics that could potentially interfere in its performance in the blast furnace.

The criteria adopted by the coal buying model of ArcelorMittal Tubarão are based only on the energy balance and the ashes chemical analysis. In the energy balance, the ratio between heat supplied by carbon combustion and the heat consumed by the cracking of water and volatiles, results in the potential rate of coke replacement by coal. The higher the calculated replacement rate, the more adequate to the process such coal is, considering that less coke will be used to produce a ton of pig iron. In the chemical composition of the ashes only the contents of phosphorus and alkalis, are analyzed, factors that could negatively interfere in the quality of the pig iron and in the useful lifetime of the blast furnace. Although adequate considering the energy parameters, the current model does not foresee possible consequences to the stability of the production process, taking into consideration that, on many occasions, two coals apparently identical for the current model affect the stability of the process in very distinctive ways. Considering that currently there is not enough knowledge about the intrinsic characteristics of coal that would allow for a selection and consequently for an adequate purchasing, a study should be carried out to supply complementing criteria to the energy model used by ArcelorMittal Tubarão, focusing the investigation on the coal characteristics that potentially interfere in the stability of the blast furnace.

The objective of this work is the realization of a comparative study between the mineral coals used by ArcelorMittal Tubarão, aiming to determine complementing criteria to the energy model currently used for the mineral coals purchasing qualification used for injection in the blast furnace. With a view to this, material characterization techniques were employed allowing for the mapping of the characteristics of the coals which potentially affect the stability of the pig iron production process.

2 METHODOLOGY

At ArcelorMittal Tubarão pulverized mineral coal is injected through the blast furnace tuyeres aiming to reduce the coke consumption. The injection is generally a mix of two or thee different coals, aiming to obtain the quality required by the production process, associated with the smallest cost. The coal mix is also interesting regarding supply strategic factors and supply logistics during moments of high demand for this raw material.

The permeability is one of the main control parameters used as reference in the qualification of the stability of the blast furnace operation. One of the main permeability indexes used by ArcelorMittal Tubarão is the "DP/V", which is derived from the Ergun equation.

The higher this index, the greater the difference between the blast pressure and the top pressure of the furnace, suggesting a smaller permeability. The smaller the permeability, the greater the difficulty for the gas generated in the combustion zone to flow through the bed and reduce the metallic oxides. When this parameter has a high value, one of the countermeasures usually adopted is the reduction of the blast volume through the tuyeres with an aim to decrease amount of gas generated in the furnace. The consequence of the reduction in the blast volume is a decrease in the blast furnace productivity, since less gas per time unit would be made available for the metallic oxides reduction reactions.

Table 1 shows operational data referring to three different mixes of coal used in the blast furnaces of ArcelorMittal Tubarão. The first one is composed of Anthracite (AT) and BO coal, the second, of RU and BO coals (in two different concentrations) and the third one by RU and AT coals.

Table 1 – Summary of operational variables and coal consumption (PCR) during the use of the different mixes.

BLEND	Prod.	Coke Rate	PCR	Small Coke	Fuel Rate	Air Blow	O2 rate	Air moisture
RU AT BO	t/day	kg/t	kg/t	kg/t	kg/t	° C	%	g/Nm^3
0% 55% 45 %	4.066	265	190	23,86	479	1.253	5,73	24,32
20% 0% 80 %	4.002	263	196	23,64	482	1.254	5,80	24,19
40% 0% 60 %	4.026	266	200	23,93	490	1.257	5,80	24,48
48% 52% 0 %	3.953	267	196	24,02	486	1.252	5,74	23,36

Analyzing Table 1 one can notice that, with the RU coal, there is a growing trend in the coal consumption (coal injection rate or PCR) to keep the same thermal level in the blast furnace. Figure 1 exhibits the results of the blast furnace permeability index and the follow-up of the permeability index during the change of the injected mix from BO + AT to RU + AT and, from RU + AT to BO + AT. Some operational instabilities were noticed when a mix with RU was used. Such instabilities reflected in the index DP/V and, consequently countermeasures for the blast volume were taken. With the replacement of the RU for the BO coal, the process is more stable and the DP/V tends to stabilize at lower values. Considering that other variables that may affect performance remained constant (or with non-significant variations), the instabilities mentioned before can be attributed to the use of the RU coal. Theoretically, according to the model used by ArcelorMittal Tubarão, great variations of the process should not occur with the change of the mixes used, once the RU and BO coals present very similar chemical and energy characteristics.

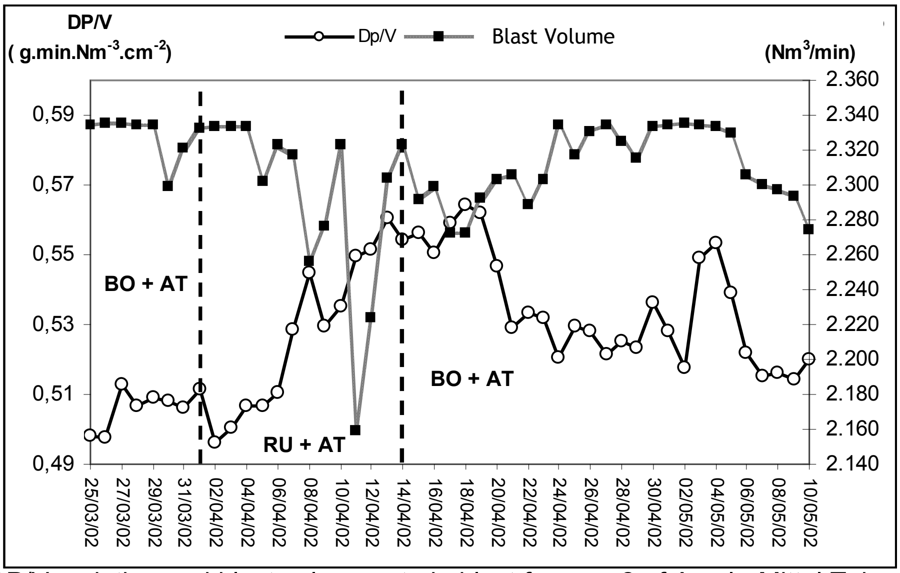

Figure 1 – DP/V variation and blast volume rate in blast furnace 2 of ArcelorMittal Tubarão. (1) shows the period of use of the mix BO + AT, (2) refers to RU + AT and (3) is back to BO + AT.

Searching to determine the causes for the difference in the performance of the coals, a study was carried out comparing the two coals named RU and BO, aiming to find differences in their properties that could potentially offer evidences of different behavior in the production process, since the first responded negatively and the second had a positive response when used in the ArcelorMittal Tubarão blast furnace.

Both coals present apparently satisfactory characteristics for injection in blast furnaces, with high contents of volatile materials and low ashes content. From a chemical standpoint, both coals have very similar properties, as moisture, ash content and chemical analysis. Coals RU and BO also present very similar physical-chemical properties suggesting a comparable performance in the blast furnace; however, the operational practice shows operational instabilities when using high concentrations of RU coal in the mix that is fed to blast furnace.

As already mentioned, it is believed that the performance of the pulverized coal injection in the blast furnace is related to the combustion efficiency of the organic material and to the ashes behavior within the reactor.

To better understand which factors interfere in the performance of pulverized coal in the blast furnace, this work studied the combustion of the RU and BO coals, besides a study of the ashes characterization, obtained after the complete combustion of such coals.

To evaluate the combustion behavior of the RU and BO coals conventional petrography techniques were applied, besides the use of termogravimetric analysis (TGA) and DTF (drop tube furnace).

Fusibility tests, high temperature viscosity tests, x-ray diffraction and scanning electronic microscopy were carried out in the ashes characterization.

The ultimate analyses of the coals and chemical analysis of the ashes are not described in the methodology of this work, considering that these are basic requisites for the adopted current procedure to evaluate the quality of the coal.

2.1 Thermal Gravimetric Analysis

Samples of the RU and BO coals were analyzed to compare the results of maximum reactivity, in a thermo-scale with a CO_2 atmosphere, and the conversion or burnout was analyzed as described in Equation 1.
The samples were prepared using 30 mg of the coals with a granulometry smaller than (0,074mm). The heating rate is of 30 ^{O}C/min, starting from ambient temperature till reaching a temperature of 1050^{o}C, which is maintained until the end of the essay.
The maximum reactivity reached by the coal can be obtained from the maximum slope of the mass loss with time curve obtained through the derivative of the experimental curve.
The conversion, or burnout, represents how much carbon was converted into products. The higher these numbers, the more carbon was converted into products and the better the efficiency of the material combustion.

$$\text{Conversion} = \left\{ 1 - \left(\frac{A}{100 - A} \right) * \left(\frac{100 - B}{B} \right) \right\} * 100 \qquad (1)$$

Where:
A = Ash contents (%) present in the coal;
B = Ash contents (%) present in the unburned coal (char).

2.2 Drop Tube Furnace Combustion Test

The essay temperature is adjusted to 1300^{o}C, the feeding rate of coal fines (20 a 125 µm) is 1g/min, the gasses flow 900l/h and the atmospheres presented oxygen contents of 20%, 10%, 5%, 2.5% e 0%. For each oxygen atmosphere tested, one sample of char was collected and had its conversion measured according to Equation 1. For the reactivity essay of the char samples, generated under different O_2 atmospheres, the temperature of 1050°C and air atmosphere in the thermo-scale was used. This way, further than the combustion efficiency of the RU and BO coals, the reactivity of the char generated by these coals was also monitored.

2.3 Ash Fusion Test

This method allows the observation of the melting temperatures of the coal ashes, when heated at a specific rate, in a slightly reducing or oxidizing atmosphere. The full methodology for the performance of this experiment is presented in the ASTM D 1857-87 standard – Method for the Standard Test for Coke and Coal Ashes Fusibility.

2.4 Ash Viscosity Test in A in Rotating Viscometer

The equipment used allows the measurement of the coal ashes viscosity at high temperatures. The coal ashes are loaded in a porcelain crucible and correctly positioned in a melting furnace. A torque meter is vertically positioned and an alumina rod (high melting point ~2100°C) connects the measuring cylinder (positioned inside the crucible) to the torque meter. The system is then heated to 1650°C, staying at this temperature during 20 minutes. The torque meter is turned on, initiating the continuous measurement which is registered in a computer. The system is confined in a CO_2 atmosphere and the cooling rate is of 2°C per minute down to the temperature of 1250°C. At the end of the essay, a viscosity curve in Poise is obtained based on the temperature (within the range of 1650°C to 1250°C).

2.5 Mineralogical Analysis of the Coal Ashes by W-ray Diffraction

The technique of Diffraction of X-rays was used by objective to identify the crystal phases present above 5 % in the ashes from the coals in study. For the execution of this analysis the samples of ashes went pulverised to an under 0,044 mm. The analyses were carried out of the UFRGS in a Diffractometer , model D5000 . The used radiation in the conditions of 40 kV and 25 mA. .

3 RESULTS AND DISCUSSION

The following results arise from the methodology proposed.

3.1 Ultimate, Ash Chemical and Petrography Analyses

Table 2 presents the ultimate analysis of the BO and RU coals. It can be noted that both present practically the same value for volatile materials, ashes and moisture contents. The ashes chemical analyses are shown on Table 3 and the petrography on Table 4.

Table 2 – Ultimate analysis of RU and BO coals.

Item	Coal BO	Coal RU
Moisture (%)	3,92	6,1
Ash (%)	10,33	9,58
Volatiles (%)	36,73	37,94
C (%)	73,7	72,9
H (%)	4,62	4,57
N (%)	1,49	1,62
O (%)	8,8	10,5

Table 3 – RU and BO ash coals analyses.

ITEM	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5
BO %	59,13	20,97	7,66	2,7	2,68	0,44	1,81	0,82	0,1
RU %	70,7	18,47	5,87	0,86	0,92	0,33	1,41	0,61	0,26

Table 4 – Macerals and Mineral contents in volumetric %.

MATERIAL TYPE	RU COAL	BO COAL
TOTAL VITRINITE	78,4	84,5
TOTAL LIPTINITE	1,0	0,4
TOTAL INERTINITE	20,6	14,8
TOTAL MINERALS	3,0	4,0

The results of the analysis do not show significant differences, not being possible to establish a concrete understanding regarding the results obtained in the blast furnace.

3.2 Thermogravimetric Analysis

According to the experiment, the RU coal presents a slightly accentuated conversion rate, resulting in higher reactivity as shown in Figure 2. Although very similar, these behaviors were unexpected, taking into account that the RU coal, when used in the blast furnace, causes instabilities in the process, suggesting lower combustion efficiency when compared to the BO coal.
Another way of analyzing the reactivity of the coals tested is by derivative curve obtained in TGA. Figure 3 shows that the RU coal presents more reactivity than the BO coal in this kind of experiment.

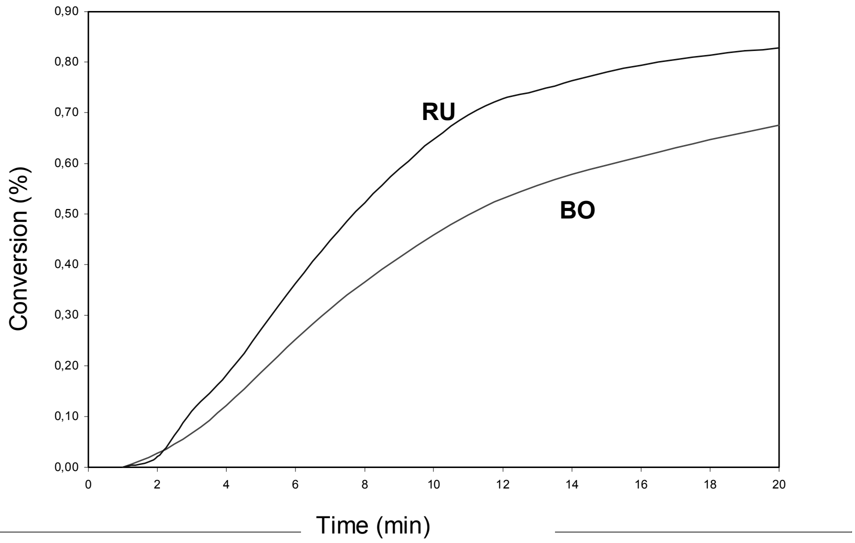

Figure 2 – Conversion or burnout for the RU and BO coals in the TGA, under CO_2 atm.

To quantify the combustion efficiency of the RU and BO coals, experiments in DTF were performed, as previously described. Figure 4 shows the results obtained. It is noted that both coals have very similar combustion efficiency in the tested O_2 atmospheres. The generated char in an atmosphere of 20% of O_2 did not present difference of reactivity in the air. For atmospheres with less than 20% of oxygen in the DTF, it was observed that the char generated by the RU coal presented a higher reactivity to the air when compared with the char generated by the BO coal.

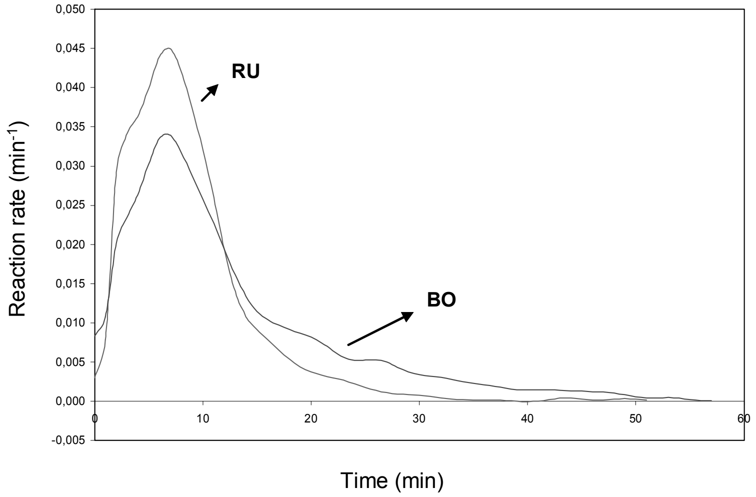

Figure 3 – RU and BO coals reactivity in a thermo-scale

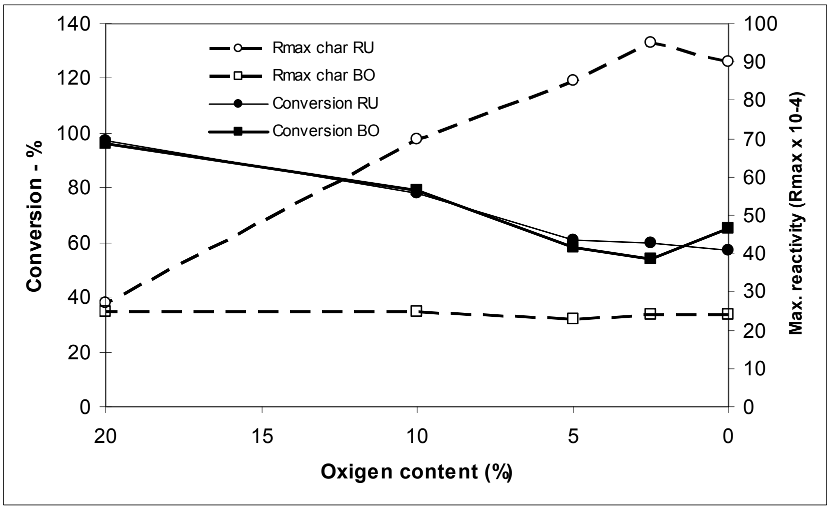

Figure 4 – Combustion tests results under various oxygen atmospheres in DTF and reactivity in TGA, under air atm, of the char generated by RU and BO coals.

Such results suggest that both coals present similar combustion efficiencies, however, the char generated by the RU coal presents a higher reactivity with the air. Again, these results were not expected, considering the operational difficulties observed during injecting a mix with high RU content, what suggested that such coal had smaller combustion efficiency or smaller char reactivity. Perhaps the ashes chemical composition could influence the char reactivity results in the TGA, considering that these are obtained in the DTF at 1300°C. The RU coal should present ash with a higher melting point and, furthermore a higher interval between the melting temperature and total fusion. Possibly, by these characteristics, the pores and fissures in the particles surface of the char generated by the RU coal are not obstructed, facilitating the O_2 contact with the remaining Carbon. On the other hand, the char generated by the BO coal should be confined by a layer of ashes with little porosity, preventing the contact of the O_2 in the air with the remaining organic material.

The results obtained in the combustion comparative study between the RU and BO coals were not enough to explain the behavior shown in the operation of ArcelorMittal Tubarão blast furnaces.

3.3 Ash Fusion Test of RU and BO Coals

The results of the fusibility tests of the BO and RU coals ashes are shown on Table 5.

Table 5 – Fusibility tests results of the ashes, through the method of ash fusion test in an oxidizing atmosphere.

Characteristic Temperatures	Unit	BO coal ashes	RU coal ashes
Deformation Initial T	°C	1240	1280
Softening T	°C	1280	1380
Hemisphere T	°C	1380	1520
Fluidityl T	°C	1440	1600
ΔT (Fusion-Softening)	°C	160	220

It is observed that the results present a tendency of the RU ashes to be more refractory than those of the BO coal. This means that the ashes of the RU coal completely melt at higher temperatures, above 1500°C, and, besides that, show a greater interval between the start of softening and complete fusion and flowing. Taking the results to the blast furnace process, one wishes that the coal ashes have a low deformation initial temperature and a low melting point. Thus, one hopes that the ashes are more easily drained through the coke active zone and the deadman, showing a smaller trend to the formation of the holdup phenomena, which will prevent the ascending gasses flow and the descending liquid flow. Although results suggest that the RU coal ashes are less adequate to the blast furnaces, the fusibility results alone are not enough to characterize the ashes behavior at high temperatures. The viscosity values are of major importance to describe the easiness or difficulty of the liquid ashes to drain through the coke particles in the lower part of the blast furnace.

3.4 Ashes Viscosity Tests

The results of the ashes viscosity tests are presented in a graphic form on Figure 5. The behavior of the viscosity of BO coal ashes presents a typical characteristic shape of completely fluid slags, where the viscosity has a moderate relation with the temperature, up to a given temperature. For values smaller than 1425°C, a sudden increase of the viscosity occurs, suggesting the start of a solid phase in the ash structure. However, for higher temperature values (around 1600°C), the viscosity shows values in the range of 10 to 12 Poise.

The behavior of the RU coal is much different than the one for the BO coal. For the whole range of tested temperatures, the viscosity values are extremely high, even for high temperatures (in the range of 1600°C) the viscosity is not inferior to 300 Poise. The RU coal viscosity curve is typical of an acid material, such as aluminous-silicates and boron-silicates, being possible that solid structures still exist in the material structure.

According to Campos,[(2)] it is admitted for blast furnaces to work with viscosity values up to 15 Poise for the hearth slag. This final slag is the result of oxides interaction after several stages, being that the primary slag is formed in the cohesion zone, the secondary slag is formed by the primary slag and by the incorporation of fluxing agents along the dropping zone, and the final slag is the result of the incorporation of the PCI ashes by the secondary slag.

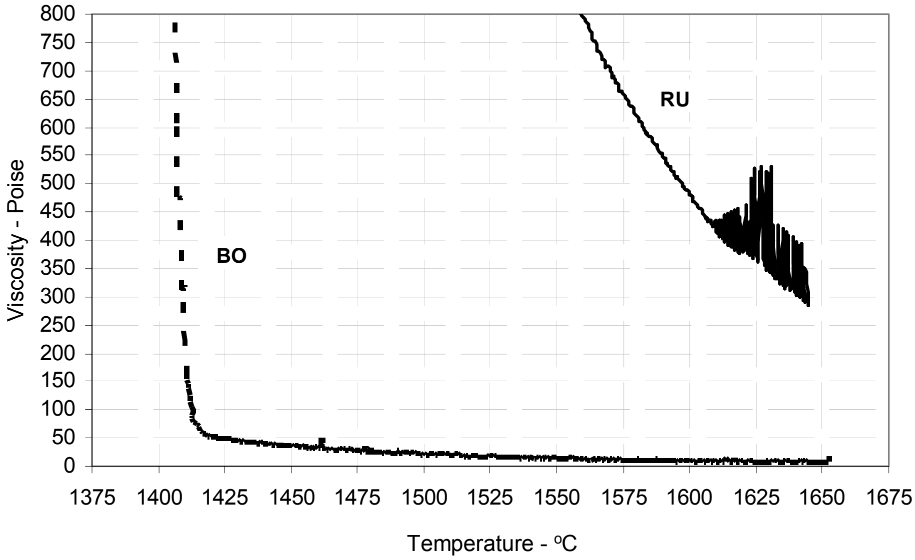

Figure 5 – Test results as function of the temperature, under oxidizing atmosphere, with a rotation viscosimeter, for the RU and BO coal ashes.

Although the PCI ashes directly contribute to the formation of the final slag, small differences in the composition of the coal ashes which comprise the injected coal mix, do not significantly alter the composition of the final slag, considering that they only represent 7% of the slag mass (kg/t pig iron). Thus, when injecting a coal with ashes of high viscosity, this does not directly reflect in the viscosity of the final slag. Despite this characteristic, the mechanism of performance loss may be related to the behavior of the coal ashes at high temperatures, locally acting in the lower part of the Blast furnace, mainly in the neighborhood of the combustion zone, or even in the zone of active coke and on the surface of the deadman, causing instabilities in the ascending gasses flow and in the flow of descending liquids.

3.5 XRD – X Ray Diffraction

Being the ashes a concentrate of the inorganic matter from the coal, it is possible to check more in detail the mineral contained phases. Nevertheless, the process of the combustion carried out of 850 ^{o}C , its possible to see severals changes (transformations, decompositions and interactions) regarding the mineral matter from the coal.

The results of XRD for the ashes from the coals RU and BO are shown in the Figure 6.

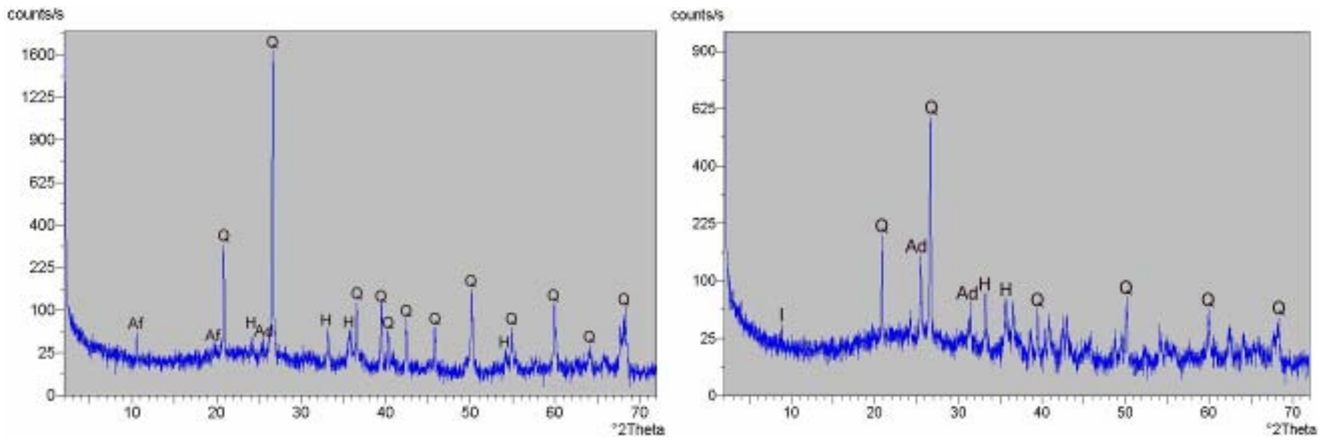

Figure 6 -Ashes from the coals RU (left) and BO (right).; Q = quartz - SiO_2; H = hematite - Fe_2O_3; Ad = anhydrite - $Ca(SO_4)$; Af = anphibole - $Ca_2Mg_4Al_{0,75}\ Fe^{3+}_{\ 0,25}(Si_7AlO_{22})(OH)_2$ e I = illite- $K_{0,5}(Al, Fe, Mg)_3(Si, Al)_4O_{10}(OH)_2$.

In diffractogram of RU the following minerals were identified: quartz, hematite, anhydrite and amphibole. The diffraction referring to BO coal ashes, phases which are similar to RU (quartz, hematite and anhydrite) were detected, with the distinction that, instead of amphibole phase, illite was found.
The relation approached quartz obtained from this method is 20: 7 for the ashes from the coals RU and BO, respectively. This estimate agrees with the results obtained by the chemical analysis of the ashes, where the ashes from the coal RU showed that its is more richer in silicon that the ashes from the coal BO (melhor colocar de outra forma essas duas últimas frases, conforme a seguir: In function of the intensity peaks of this x-ray diffraction patterns, from the coal RU showed that its is more richer in silicon that the ashes from the coal BO. The phase anhydrite contained in the ashes is present in proportional amount of calcium and sulphur that its found in the chemical composition of the samples. This observation permit to affirm that the ashes from the coal BO it is richer in anhydrite that the ashes from the coal RU.

3.6 Mechanism of Performance Loss in the Blast Furnace Related to the Pulverized Coal Injection

Most studies relating to the pulverized coal injection in blast furnaces concentrate in the combustion evaluation of the coals organic materials considering that this is the main requisite for this fuel. If a certain coal type presents inadequate combustion characteristics so that it does not completely burn in the combustion zone, a large quantity of fines will remain in the blast furnace. These fine particles are a mixture of carbon with ashes (char) which, if not consumed by the reaction with CO_2 (solution loss), would deteriorate the permeability of the blast furnace, resulting in operational instabilities. On the other hand, even if the organic material completely burns in the combustion zone, around 10% of the total of the injected coal will be introduced in the interior of the reactor as ashes. One can expect that this mineral material also influences the performance of the injected coal and of the blast furnace. Generally, for a complete characterization of this material, it is necessary to perform experiments that supply evidences for both the combustion characteristics and the ashes characteristics at high temperatures.
To simulate and compare the combustion behavior of the RU and BO coals, the following experiments were used in this study: Elementary chemical analysis; Petrography analysis; Coals reactivity to CO_2, measured in TGA; Coal reactivity in

several O_2 atmospheres, measured in the DTF (''Drop Tube Furnace''); Char reactivity to the air, in a TGA.

To characterize the behavior of ashes at high temperatures, the following analyses were selected: Ashes chemical analyses, through X-Ray fluorescence; Ashes fusibility, measured through the ash fusion test, Ashes viscosity, measured through a rotation viscosimeter, X-ray diffraction (DRX) and scanning electronic microscopy (SEM).

The limitations of the selected experiments to simulate the coals burnout in the combustion zone, the combustion results did not show significant differences that account for the worst performance of RU in the blast furnace. The char generated by the RU coal presented an anomalous behavior of diminished reactivity (in air atmosphere) as one increases the O_2 contents in the DTF. Despite this behavior, when the results for the RU with the BO, it could be noted that, in all O_2 atmospheres used in the DTF, the char generated by the RU has higher reactivity than the BO. As both coals have similar reactivity to CO_2 and, the char generated by the RU coal is more reactive in relation to the one of BO, the worst performance of the RU coal in the blast furnace can not be attributed to its combustion characteristics.

The experiments carried out for the characterization of ashes at high temperatures showed very distinct results. The RU ashes, besides being more refractory, show a higher interval between the start of softening and the complete fusion. Other very important result is the high viscosity of RU coal ashes, presenting a lowest value of 300 Poise at 1600°C, against 10 Poise for the BO coal at the same temperature. The results of the fusibility and viscosity indicate a greater difficulty of the ashes generated by the RU coal as much to melt as to flow in the lower part of the blast furnace.

Considering the obtained results in the experiments and the evidences found in the process, a flowchart was created to explain the blast furnace performance loss, related to the characteristics of the mineral coals injected through the tuyeres. This flowchart is shown in Figure 6.

If the injected coal does not burn completely in the combustion zone, the fines will be introduced inside the blast furnace (coke active zone or even the deadman zone). As part of the coal does not burn (less heat supply), the immediate action normally adopted is to increase the injection to compensate for the thermal deficit, increasing the total consumption of fuels per time unit. With the increase of the injection rate and as the coal has low reactivity, the cycle is repeated so that a large quantity of fines will be deposited in the lower part of the furnace, deteriorating its permeability. Depending on the intensity of the impermeability, the descending liquids have a peripheral flow in the lower part of the furnace, exchanging less heat with the deadman, as illustrated in Figure 7.

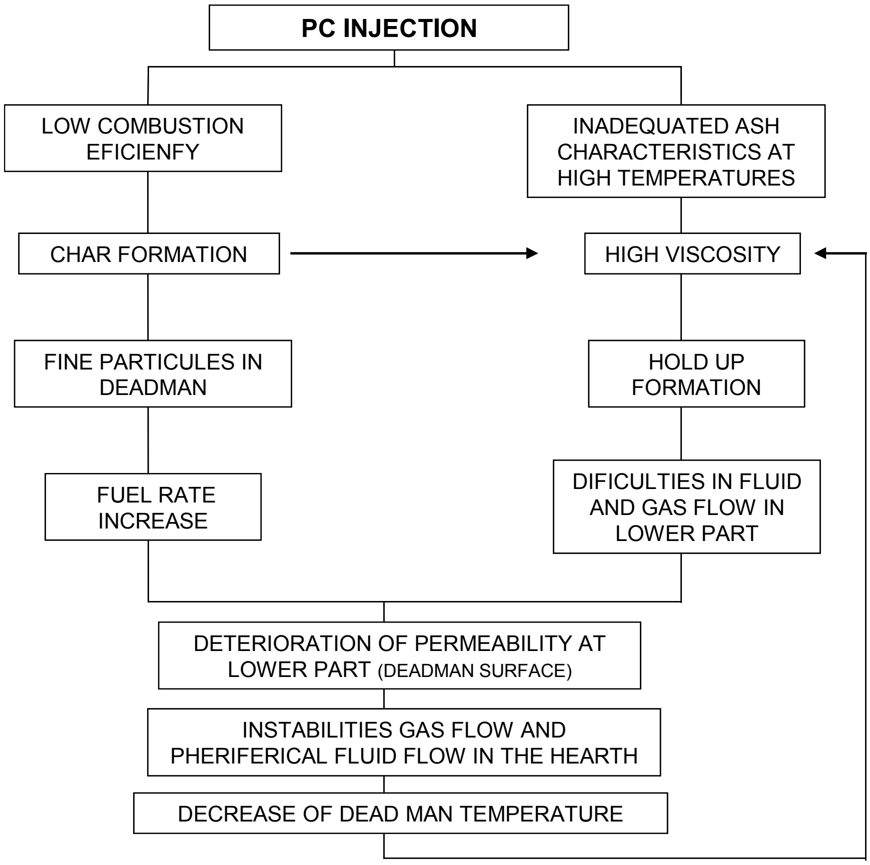

Figure 6 – Flowchart for the analysis of the blast furnace efficiency loss related to the characteristics of the mineral coal injected through the tuyeres.

On the other hand, if the coal ashes (here considered a product of combustion) present potentially inadequate characteristics, operational instabilities will also be generated. Ashes with high melting starting and ending temperatures and high viscosity, such as the ones of the RU coal are difficult to flow, creating barriers or hold up in various parts located in the deadman surface or at the coke active zone. Such barriers prevent the easy flow from descending liquids through the interior of the deadman, as illustrated in Figure 7, causing peripheral flow, less heat exchange and lower temperatures in the interior of the dead man. As viscosity depends on the temperature, the cycle repeats itself. The extreme injection situation would be where the injected coal had low combustion efficiency (with great tendency to char formation) and also high viscosity ashes.

In the specific case of this study, the low RU performance was attributed to the high viscosity of its ashes at high temperatures, when using mixes with over 40% of this coal.

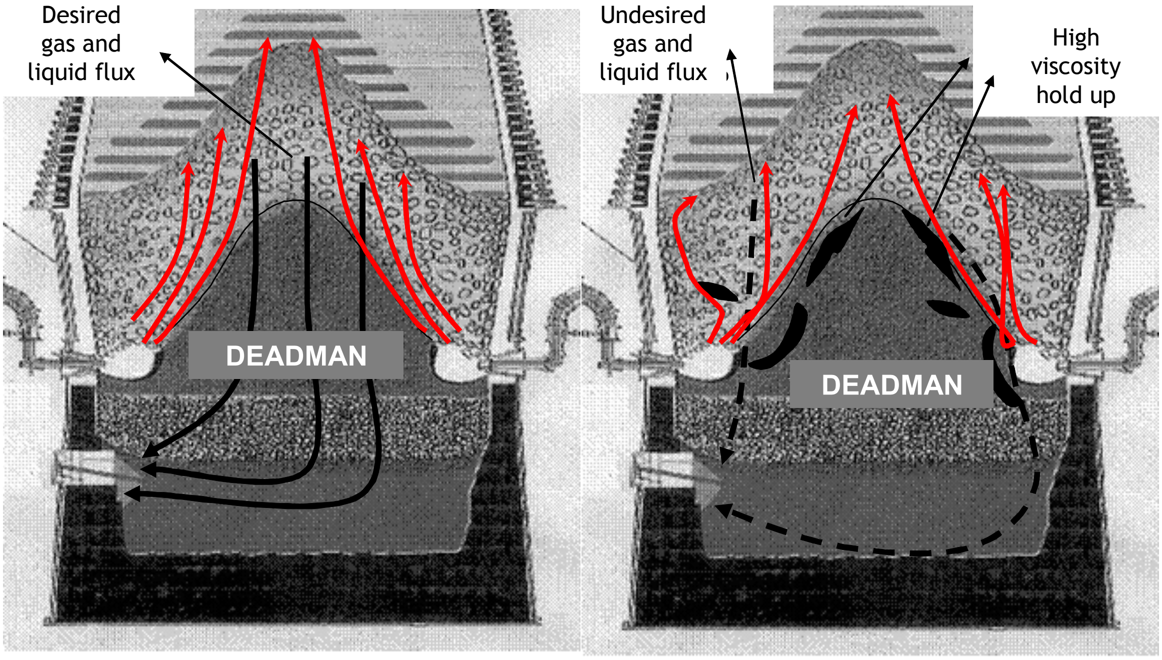

Figure 7 – Illustration of the mechanism of loss of performance in the blast furnace related to characteristics of the mineral coal injected through the tuyeres.

4 SUMMARY AND CONCLUSIONS

This work is intended to establish a methodical procedure which would serve as a basic tool for the selection of coals and also for foreseeing the behavior of new types of mineral coals to be tested in ArcelorMittal Tubarão blast furnaces. With a view to this, some tests and analyses that, within the imposed limitations, try to simulate the combustion and ashes behavior of the coals at high temperatures. We selected two coals with high volatile contents which present distinct behaviors in the blast furnace. The RU coal presents a tendency of deterioration of the operational stability of the blast furnace when injected at high proportions in the mix, while the BO coal, although very similar, gives very satisfactory results.

Besides chemical and petrography analyses to simulate the reactivity in the combustion process thermo-gravimetric tests were carried out in a CO_2 atmosphere, tests at the DTF equipment under several O_2 atmospheres and to monitor the char reactivity, thermo-gravimetric tests were done in an air atmosphere. Fusibility tests, viscosity at high temperatures, X-Ray diffraction and scanning electronic microscopy (SEM) were used to monitor the behavior of the ashes at high temperatures. The above mentioned experiments were done with the RU and BO coals to investigate which characteristics are responsible to the coal performance at the blast furnace.

Through the experiments carried out one can conclude that the combustion tests are not enough to characterize the performance of a determined type of coal in the blast furnace. Although limited to simulate the combustion zone, the reactivity tests are extremely important to characterize the basic requisite of the fine injection process and their results should be used in the purchasing process, mainly when trying to purchase low volatiles content coals. Through the results found in the viscosity tests the RU coals ashes present high viscosity even at high temperatures, while the BO coal ashes present low viscosity. This characteristic can be very relevant in the determination of the performance of the coal in the blast furnace, taking into account that high viscosity ashes will cause the formation of barriers at determinate regions of the low part of the furnace, that possibly, will deteriorate the liquids and gasses flow, causing operational instabilities.

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