THE MINI BLAST FURNACE – A CHALLENGE FOR A NEW IRONMAKING (1)

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ABSTRACT

The non-integrated sector of pig iron production in Brazil has an important role in the national siderurgy since it was responsible for 22% of the national production of pig iron in 1999.

This paper presents a short history of blast furnace, which started with charcoal. At present, Brazil is the only country in the world to use this thermoreducer. The present process of charcoal mini blast furnace is basically the same as the old processes of metal production, but with a much larger production and a lower specific consumption of carbon.

Charcoal mini blast furnaces are located mainly in Minas Gerais, but the Carajás region has started to show a substantial growth in their numbers.

The operation of charcoal mini blast furnace is rather distinct from the coke one in that their raw materials have rather distinct characteristics.

Finally, it will be shown that it is possible to obtain a good operational efficiency with charcoal mini blast furnace.

Key words: Blast Furnaces; Charcoal.

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1. Introduction

Presently Brazil has a large hot metal production through blast furnaces which use charcoal as a thermoreducer and an energy source. These companies are not integrated, that is, their final product is pig iron. The growth in this sector started in the early 1970's as a result of the availability of cheap and good quality raw materials (native wood charcoal and granulated iron ore). In addition, the return of the investment in the construction of mini blast furnace is very fast.

Nowadays, this sector is consolidated and has a fundamental role in the national and international siderurgy since the country is a major supplier of primary iron.

This paper presents a brief history of blast furnace, and of Minas Gerais, which will help understanding the present process described here. To illustrate the importance of this segment, a profile of the non-integrated pig iron industry in Brazil is drawn.

Finally, the charcoal and coke pig iron blast furnace production processes are compared. This allows delineating low cost improvements that can be made in the pig iron charcoal blast furnace production process.

2. Brief history of the blast furnace

In nature, iron is found in association with other elements, mainly oxygen, in the form Fe_2O_3 (hematite) or Fe_3O_4 (magnetite). The first contact men made with the metal was through fallen meteorites which contained iron, besides 5 – 26% nickel. The origin of the word is from Latin "sidus", which means star.

The first iron oxide reduction process was by chance: the stones that were used to surround fires changed properties with time. In fact, what happened was: iron ore (Fe_2O_3) + C(from wood) + heat (from wood and air burning) = reduction of iron oxides and production of metallic iron. This iron had a low carbon content because carbon was not incorporated as a result of the low process temperature. Therefore, the first metal to be produced was steel (iron with up to 2% carbon) and not pig iron (iron with about 4% carbon).

The way the process was carried out evolved as time passed, but basically what occurs is the mixture of iron and charcoal and a blast (or natural air supply). The burning of the charcoal generates the heat and the reducing gases (CO), which allows the reduction of iron oxides and the production of a solid mass (paste like at best) of iron, with low carbon content and slag. This material was heated and forged to obtain the adequate forms for its use. Figure 1 shows a loup furnace used in the year 100 BC for the production of the metal.

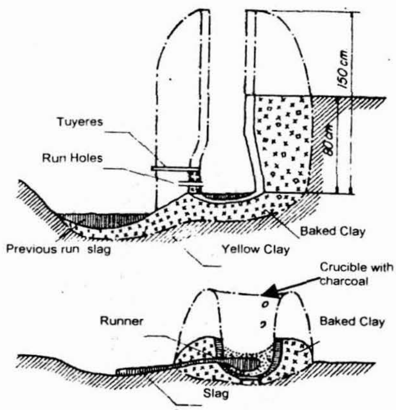

Figure 1 Loup furnace from 100 BC used in the production of steel

A method used and which dominated the production of the metal in the world for a long period (centuries XI to XV) was the Catalan Forge, whose scheme is shown in figure 2.

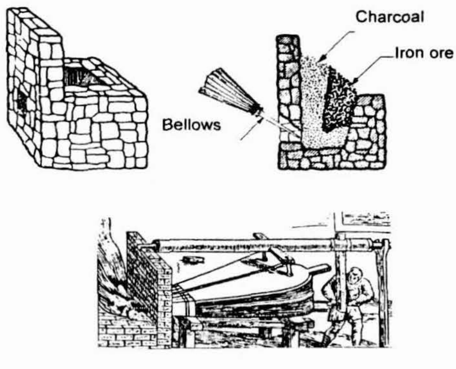

Figure 2: Catalan Forge used in the production of the metal.

The precursor of the present blast furnace was the "Stuckofen", which was used in the region now known as Germany from 1340 on. Besides being taller than the traditional furnaces of the time (it was 3 – 4.8 m high), it innovated in the profile, as shown in figure 3. Its production capacity was larger than that of the Catalan Forge, and produced a liquid metal with a carbon content larger than that of pig iron! Due to its height, its larger capacity to hold charcoal, and its two bellow tuyeres, it was possible to reach higher temperatures and a larger time of residence of the metal in the furnace, which led to a better dissolution of the carbon in the iron. These furnaces also produced a metallic mass containing slag and iron with low carbon as the previous furnaces did (Catalan Forge type.)

The first blast furnace to produce only hot metal was the "Flussofen", in the Rhine valley in the region presently known as France, Belgium and Germany, back in the 1300's.

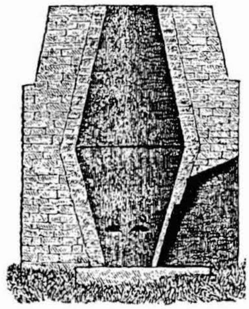

Figure 3 "Stuckofen" Furnace from 1340.

As an example of the evolution of pig iron equipment and production technique, figure 4 shows a blast furnace from the USA,1645. The bellows were operated by a hydraulic mechanism and the furnace was located near forests (charcoal), iron ore deposits and rivers (to move the water wheel). It could produce 1 ton per day.

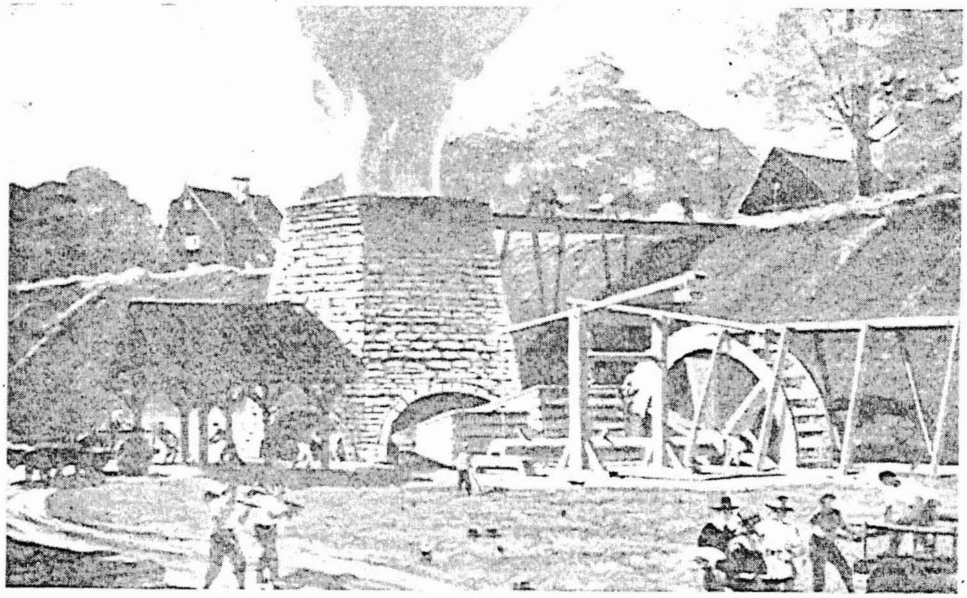

Figure 4 Blast Furnace from the USA, 1645.

With charcoal production logging restrictions, mainly in England, the use of coke in blast furnaces was introduced. The blast furnace with this new thermoreducer was first used in England, 1709. At present, charcoal blast furnaces are still in use only in Brazil.

Other major evolutions:

. 1780: bellows start to be operated by steam engine;
. 1828: tuyere blast air started to be heated, with a considerable economy of fuel carried to the top;
. 1832: use of blast furnace top gas to heat blast air patented;
. 1857: heat exchanger with fire bricks, called Cowper;
. 1910: turbo blowers for air blast in the tuyeres;
. 1910: first iron ore sintering machine started operating, Dwight Lloyd;

The first initiative to produce iron in Minas Gerais was made only in 1827 by Jean Antoine Félix Dissandes, Monlevade, who opened a Catalan Forge in Caeté. It was only in 1884 that a charcoal blast furnace, Usina Esperança (Esperança Mills), was built in Itabirito. It had a daily production of 6 ton of pig iron.

In 1925, the first integrated mill in South America was opened in Sabará, Companhia Siderúrgica Belgo Mineira, a result of a partnership between Aciéries Réunies de Burbach-Eich-Dudelange – ARBED, a Belgian Luxembourgian consortium, and Companhia Siderúrgica Mineira, which originally produced iron with Catalan Forge. In 1937, Belgo Mineira opened its second mill in Brazil – the largest charcoal integrated mill in the world – introducing a pioneer vision in America: reforestation based on eucalyptus to supply the blast furnace demand for charcoal.

The early 1970's saw an intensification of the construction of mini blast furnaces in Minas Gerais. Carrousel type casting generated a product (pig iron) with dimensions adequate for handling and transportation. The non-integrated production sector was consolidated.

3. The present process

The production capacity of the charcoal mini furnaces used by non-integrated mills to produce pig iron ranges from 55 to 350 ton/day.

Basically, the pig iron production process in mini blast furnaces follows the same scheme of the beginning of the process, which is the mixing of a metallic load with charcoal and blast. Figure 5 summarizes it.

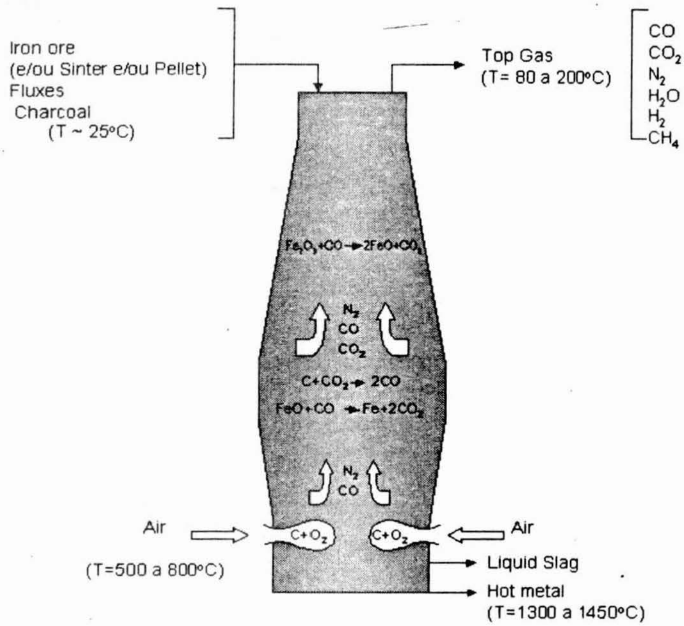

Figure 5: Mini blast furnace pig iron production process

The commercialization product may be solid pig iron, solid ingots, or even hot metal, which is transported by trucks in pots and used by companies located near the blast furnace (between 10 to 20 km.)

Figure 6 exemplifies the production flowchart of pig iron of an enterprise of the sector. It can be observed that not all the top gas is used to pre-heat the air. A large part is burned without any use.

The top gas cleaning system is basically made up of the powder balloon, cyclones and in some enterprises, washers.

The heat exchanger is a Glendon, which requires an investment much smaller than that of a Cowper. However, it is less efficient and has a maximum blast temperature of 800°C. It is made up of a row of cast iron bottles interconnected by canals or stainless steel pipes. The blast furnace gas is burned outside the bottles or pipes with air to heat them. The cold air is blown in and passes inside the bottles or pipes and is heated.

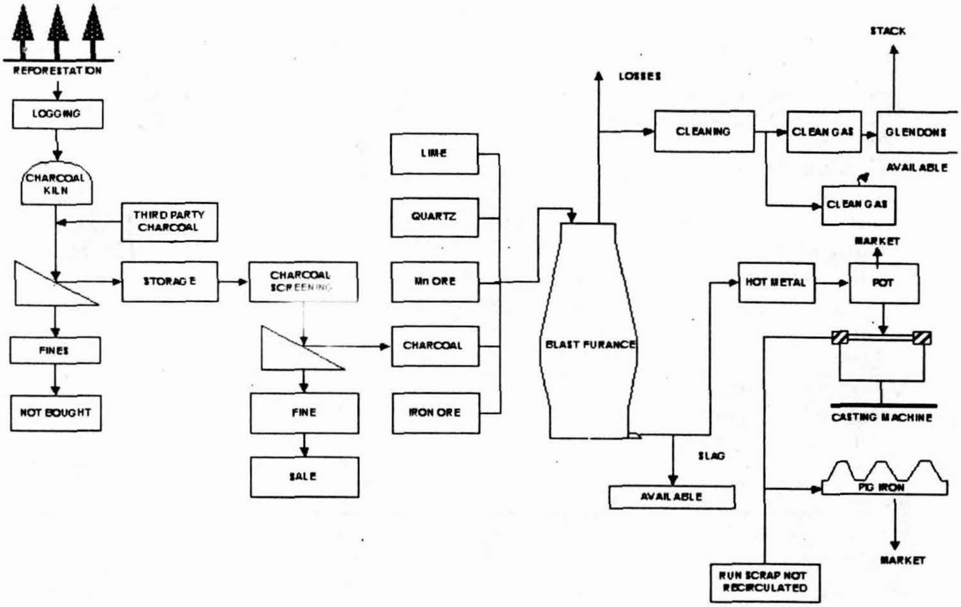

Figure 6 General flowchart of pig iron production of a non-integrated companies

4. Present situation of non- integrated pig iron industry in Brazil

Table 1 shows the nominal pig iron production capacity of charcoal mini blast furnaces in Brazil and the localization of the companies in the state.

The yearly nominal capacity of the sector is 8.422.800 tons. In 2000, 6,145,377 tons were produced, 73% of the total capacity. 60% of this total was exported, mainly to the US (83% of export).

In 1999, Brazil produced a total of 24,548,580 tons of pig iron, being 17,738,793 tons (72.3%) produced by integrated coke mills, 5,401,413 tons (22%) by non-integrated charcoal mills, and 1,408,374 tons (5.7%) by integrated charcoal mills. These numbers reinforce the importance of the non-integrated sector for the production of primary iron in Brazil.

Table 1 Location of pig iron producers by state and nominal production capacity.

Local	Companies	Blast Furnaces	Nominal capacity (ton/month)
Minas Gerais			
West region			
Divinópolis	6	12	54,300
Itaúna	1	3	15,000
Other municipalities	11	16	82,200
Sum	**18**	**31**	**151,500**
Northwest region			
Sete Lagoas	17	32	197,600
Other municipalities	4	6	26,000
Sum	**21**	**38**	**232,600**
Metallurgic region			
Betim/Contagem	2	9	44,300
Other municipalities	3	4	21,500
Sum	**5**	**13**	**65,800**
Total	**44**	**82**	**449,900**
Espírito Santo	**4**	**8**	**63,500**
Carajás Region			
Maranhão	7	15	137,000
Pará	2	5	43,500
Total	**9**	**20**	**180,500**
Mato Grosso do Sul	**1**	**1**	**8,000**
GRAND TOTAL	**54**	**111**	**701,900**

5. Comparison between charcoal and coke blast furnaces

Although the processes are basically the same, the different proprieties of charcoal and coke lead to two different situations in practice. Table 2 shows the characteristics of charcoal and coke.

Charcoal presents a much larger variation in its properties, as a function of the type of wood and the carbonization process variables. On the other hand, coke may have a greater stability of characteristics. A consequence of this is that the day-to-day operation of a charcoal blast furnace is much more complex and subject to disturbances.

In contrast to charcoal, coke practically does not present volatile materials. These volatile materials contain much CO and H_2, combustible gases that exit from the top. Therefore, the calorific power of the top cages of a charcoal blast furnace is much bigger that that of a coke one. This is important in the heat exchange design (Glendon or Cowper) which use these gases to heat blast air.

Table 2 Charcoal and Coke characteristics

Item	Unit	Charcoal	Coke
Fixed Carbon	%	65-75	~88
Volatile Materials	%	25-35	~1
Ash	%	2-5	10-12
Sulfur	%	0.03-0.10	0.45-0.70
Ash composition			
SiO_2	%	5-10	50-55
CaO	%	37-56	4-5
MgO	%	5-7	4-5
Al_2O_3	%	2-12	25-30
Fe_2O_3	%	6-13	5-7
P_2O_5	%	8-12	0.4-0.8
K_2O	%	15-25	2-4
Na_2O	%	2-3	1-3
Resistance to compression	kg/cm^2	10-80	130-160
Granulometric range	mm	9-100	25-75
Density	kg/m^3	180-350	550
Reactivity		higher	lower

Coke contains much more sulfur than charcoal. It is important to avoid the incorporation of this element into the pig iron. For this, blast furnaces work with high basicity slag, that is, a ratio $(CaO+MgO)/SiO_2$ larger than one, because the slag retains more sulfur. Charcoal has a problem of high alkali content ($K_2O + Na_2O$) and to increase the capacity of its slag to retain these compounds, it has to be acid, a ratio $(CaO+MgO)/SiO_2 < 0.80$. As a result of the high ash content of coke and the ash having more SiO_2, coke blast furnaces work with a larger slag volume (250 to 350 kg/pig iron ton) than charcoal blast furnaces (120 to 180 kg/pig iron ton).

As they work with more acid slag, the ramp and the crucible of charcoal blast furnaces can have silica-alumina fire bricks.

Coke has a mechanical resistance higher than that of charcoal. Hence, coke blast furnaces can be big or small. Nowadays, there are coke blast furnaces with production capacity of 13,000 ton pig iron/day in operation. The largest charcoal blast furnace produces 1,200 ton pig iron/day. A large size blast furnace requires prepared metallic load (sinter or pellet). In the case of charcoal, it is possible to use a load with 100% granulated iron ore.

6. Improvement of the operation of charcoal blast furnace

The major problem in the charcoal blast furnace operation is the large variation of the properties of charcoal. A good operation implies in a high production and a low specific consumption of carbon. High production is associated with reactor permeability. The measures necessary to assure good permeability are: making good load distribution, keeping load granulometry narrow; having good load quality; and keeping the furnace always empty of liquids (slag and pig iron).

To achieve low carbon consumption, it is most important to have efficient metallic load reduction at the upper part of the furnace. For this objective to be attained, it is necessary a permeable load of good quality (resistant and non-degradable.)

On that account, it must be sought to work with good quality iron ore and with charcoal whose characteristics varies the least, in addition to having low moisture, good mechanical resistance and high density.

Concurrently, instrumentation must be maximized within equipment cost limits and there must be a staff well trained in process actions and concepts.

And, the most important, to maintain a high operation stability, that is, to make minimal changes to operational actions and load quality as a whole.

7. Final comments

A mini blast furnace involves a process much distinct from that of a coke blast furnace, despite their operating under the same fundamental principals.

It is possible to achieve good operational efficiency for a mini charcoal blast furnace as long as good quality raw materials are used and good operational stability is maintained.

The non-integrated sector of pig iron production is an important segment of the national siderurgy and is an excellent alternative for the country to remain competitive and raise its rank in the global steel production.

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