PRODUCTIVITY IN THE BLAST FURNACE: ITS EFFECTS ON PRODUCTION COST [(1)]

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ABSTRACT

The Information Technology brought markets that were geographically distant and, as a consequence, opened the Brazilian steel market to the international concurrence. To have it economic survival guaranteed, in a market with such a strong competition, Brazilian steel companies are continuously searching for cost reduction alternatives, increasing, not only productivity in relation to the labor and raw materials, but also to obtain high outputs from their equipment. Inputs such as labor and raw materials are today highly optimized and, consequently, to improve the productivity of equipment is now a very important objective. In economy is said that, in order to reduce the cost, production level must increase. However, the blast furnace is not obedient to this law because the high preponderance of the cost of coke in the variable costs and the dependence of the coke rate on productivity. As consequence, there is a minimum point in the curve cost versus productivity of the blast furnace. In this context, many technologies are used in order to overcome the operational problems that high output levels result. Using these technologies, the blast furnace operator must be aware that the final objective it is not the productivity itself, but the company's profit.

Key words: production cost, blast furnace, productivity

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1 INTRODUCTION

The world economy is suffering dramatic changes as consequence of Information Technology. Among them, one of the most important for countries like Brazil, is how ease information is exchanged between the markets, independent of geographic barriers. In this new economic environment, the Brazilian steel market was opened to international traders, resulting in substantial variation in the internal steel prices and, consequently, affecting the profitably of the sector. Figure 1 shows the iron & steel product average price variation in the last 10 years and the internal/external price relation.

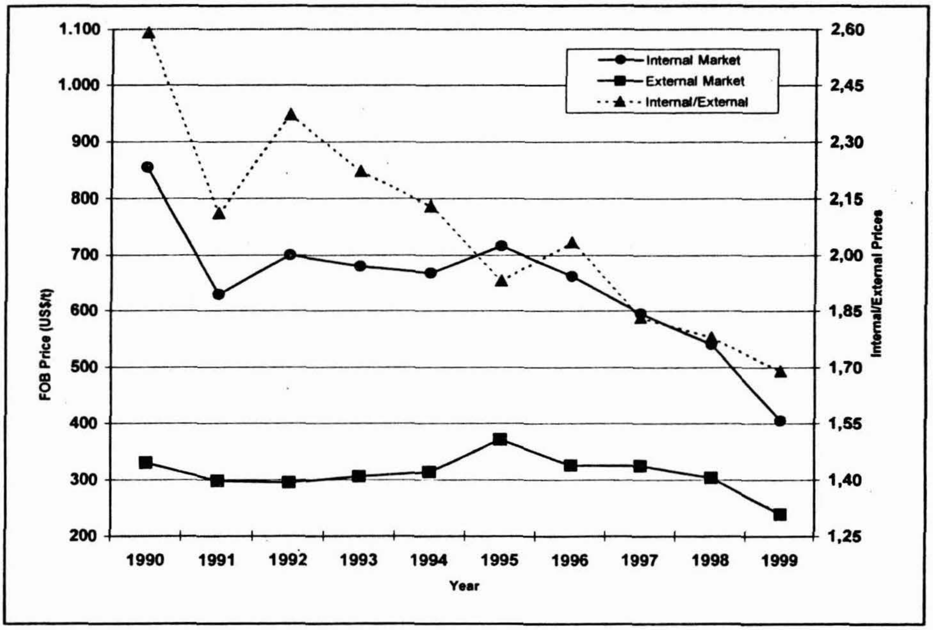

Figure 1 – Average price evolution for Brazilian iron & steel products in the last 10 years[1].

It is important to note that, although the external market price has suffered small oscillations in the period, the price paid in the internal market has dropped substantially.

These figures demonstrate the necessity for the Brazilian steel sector to find a new way to overcome this constant profitability decrease. In fact, in the last years, much has been done to increase the competitive of the steel sector, not only in the world, but also in Brazil. The administration structure has been modified in order to face this new situation in a globalize market: fusion and strategic alliances, new transnational companies, internal restructurization, etc., in order to reduce costs and increase the productivity.

Regarding the productivity, the steel companies have explored two factors to improve it. First, increasing the efficiency of the inputs (labor, raw materials, etc.).For example, Figure 2 shows the improvement of the labor productivity during the last years in the Brazilian steel industry.

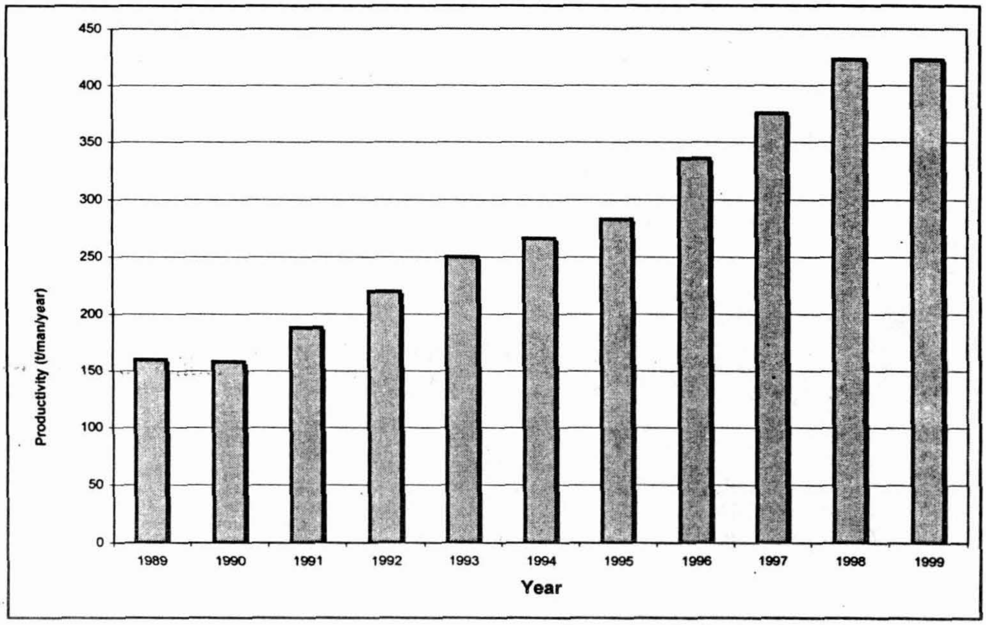

Figure 2 – Evolution of labor productivity in the Brazilian steel industry [1].

Another alternative ways to reduce costs is increasing the productivity of the equipment. Of course this alternative is valid only when there is a market to the that excess of product. Recent economical data has shown that the Gross National Product, particularly in the industrial sector, is consistently increasing, which means that this alternative will really be used to reduce production costs. An additional reason to improve the productivity of the equipment is the fact that to improve the effectiveness of labor and raw materials is becoming, gradually, more difficult because the extreme optimization of the processes. Figure 3 shows, for example, the reduction of coke rate in the blast furnace as new technologies are introduced in the process. As can be seen, the process reached such optimization level that further improvement in combustible consume is rather difficult.

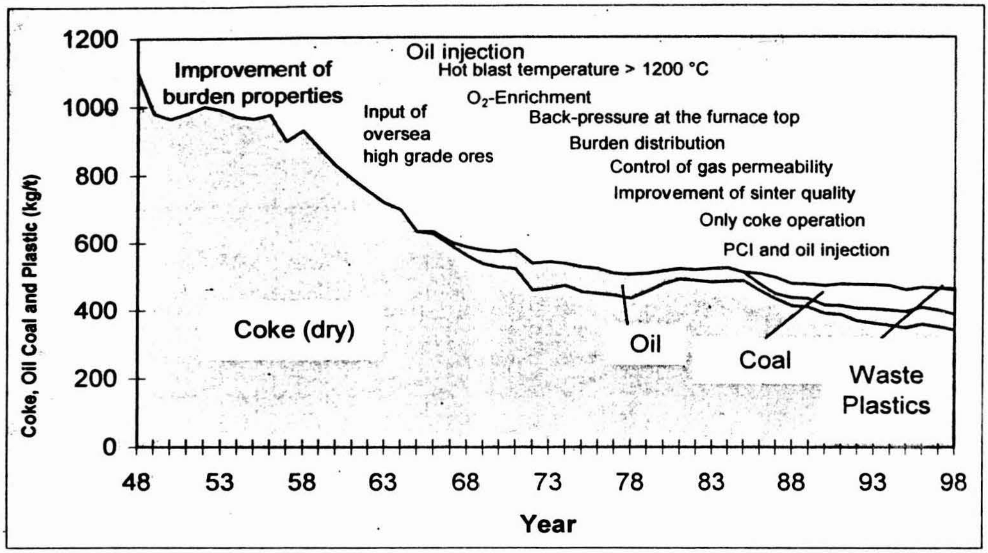

Figure 3 – Evolution of combustible consumption in German blast furnaces along the introduction of new technologies in the process[2].

It is well known the effects of increasing the production on cost: fixed costs are progressively diluted and, as consequence, the unitary production cost decreases. This is known as reduction cost due to increased scale. However, this effect is valid only when the variable costs are kept constant as the production increases. Cost in blast furnace has two peculiar characteristics. The first one is that coke represents a large parcel of the variable cost, reaching, in some situations, up to 70%. As consequence, even small variations on the coke rate affect substantially the production cost in the blast furnace. A second characteristic of blast furnace cost results from the fact that the production level affects the coke rate and, consequently, the variable cost is not constant and the rule "high production, low cost" is not always followed. In this work, the relationship between productivity and cost in the blast furnace will be explored.

2 Productivity, Coke Rate and Cost

In order to analyze the effect of productivity on the hot metal production cost, it was consider a blast furnace with a working volume of 350 m^3. For this blast furnace, the fixed cost is 150.000 US$/month and the variable cost, except coke, is 35,00 US$/t.

2.1 Productivity and Coke Rate in the Blast Furnace

Since coke represents a large portion of the variable cost in the blast furnace, it is necessary to correlate the coke rate and productivity, express here in terms of ton per day per cubic meter of working volume (t/day/m3). However, before to describe such correlation, it is also important to review some of the main parameters related to the consumption of coke in the blast furnace: heat losses, silicon content, level of indirect reduction in the shaft and gas flow through the charge.

2.1.1 Heat Losses

Heat losses in the blast furnace, expressed as units of energy per unit of time (for example, kcal/minute), depend on two group of variables: operational and construction variables. The most important operational parameter to affect the heat losses is the gas flow characteristic (central or peripheral flow). Of course, as the amount of gas flowing close to the wall increases, the heat losses also increase. Under the construction point of view, heat losses through the walls depend on the thickness and thermal conductivity of the refractories. They also depends on the type (internal or external) and characteristics of the cooling system. However, once these two types of variables are kept constant, the heat losses, now expressed in terms of energy unit by mass unit of hot metal (kcal/t HM), is inversely proportional to the production level. That is, as the productivity of the blast furnace increases, the portion of the coke rate necessary to compensate the heat losses decreases.

2.1.2 Silicon Content

Silicon is incorporated to the hot metal during dripping below the cohesive zone[3]. In front of tuyeres, silica is reduced by carbon monoxide to silicon monoxide:

$$SiO_{2(l)} + CO_{(g)} = SiO_{(g)} + CO_{2(g)}$$

As the SiO gas flows up through the dripping zone, the carbon in the liquid iron reduces it and silicon is incorporated to the metal:

$$SiO_{(g)} + \underline{C} = \underline{Si} + CO_{(g)}$$

The amount of silicon incorporated during dripping, and later in the hearth due to the slag-metal contact, depends on the temperature, FeO content and basicity of the slag, wind pressure and the time spend to reach the furnace bottom. As productivity increases, the amount of FeO in primary slag increases and part of silicon incorporated is again oxidized:

$$\underline{Si} + 2(FeO) = (SiO_2) + Fe_{(l)}$$

Also as the productivity increases, due to a higher gas flow resistance, the wind pressure increases. According to SiO reaction production above, increasing the pressure reduces the amount of SiO produced and, consequently, the silicon incorporated in the dripping zone. Another effect of higher production rates is the reduced residence time during dripping, what will also contribute to obtain lower silicon content in the hot metal. Statistic results shows that for each 0,1%Si less in hot metal the coke rate decreases between 4 and 7 kg/tHM.

2.1.3 Reduction in Shaft

Productivity affects the residence time of the metallic charge in upper part of the furnace. Consequently, as the production rate increases, the contact time between the gas and the iron oxides is reduced, resulting in a higher oxidation level at the lower part of the furnace. Since a larger amount of oxygen has to be removed in the direct reduction region, the coke rate increases.

2.1.4 Gas Flow

The resistance for gas flow through the charge increases with the square power of the gas velocity[(4)]. Since to increase the productivity it is necessary the increase the blow rate, and consequently, the gas velocity, the flow resistance increases up to a level when the descendent movement of the charge becomes irregular. This type of charge movement reduces the gas-solid contact and, in a similar way to the comments in previous paragraph, increases the coke rate. Statistic results have shown that increasing the shaft gas velocity by 0,1 m/s increases the coke rate between 2,5 and 3,0 kg/tHM.

However, there is a portion of coke rate, resulting from several physical and chemical phenomena occurring inside the blast furnace, which is kept approximately constant as the productivity is changed. The total coke rate is the sum of this part and the effects of heat losses, silicon content, reduction in the shaft and gas flow, as described above. Productivity effect on these parameters is shown in Figure 4. It is important to observe that the values shown in the figure change for each furnace and operation, and the objective of such figure is merely qualitative, in order to analyze the effects on the production cost, as it will be seen later.

In this figure it can be seen that the productivity affects the coke rate in two different ways: heat losses and silicon content effects on coke rate are inversely proportional and shaft reduction and gas flow directly proportional. These opposite tendencies results in point of minimum coke rate, as can be seen in the figure.

Since coke represents a large part of the cost, the variation of production cost with the productivity will also present a similar behavior, that is, a minimum cost will occurs to a specific productivity, as can be seen in Figure 5. It can be observed that, although the fixed cost decreases as the productivity increases (as expected), the total cost increases above a certain level of productivity due to the increase of variable cost (coke cost). This is an exception the well-known rule mentioned before, or in other words, high productivity does not necessarily means lower cost. It is interesting to note that the minimum cost does not occur at the minimum coke rate point. Due to the fixed cost, the minimum cost point occurs at a slightly higher productivity (depending on the value of fixed cost) than the minimum coke rate point.

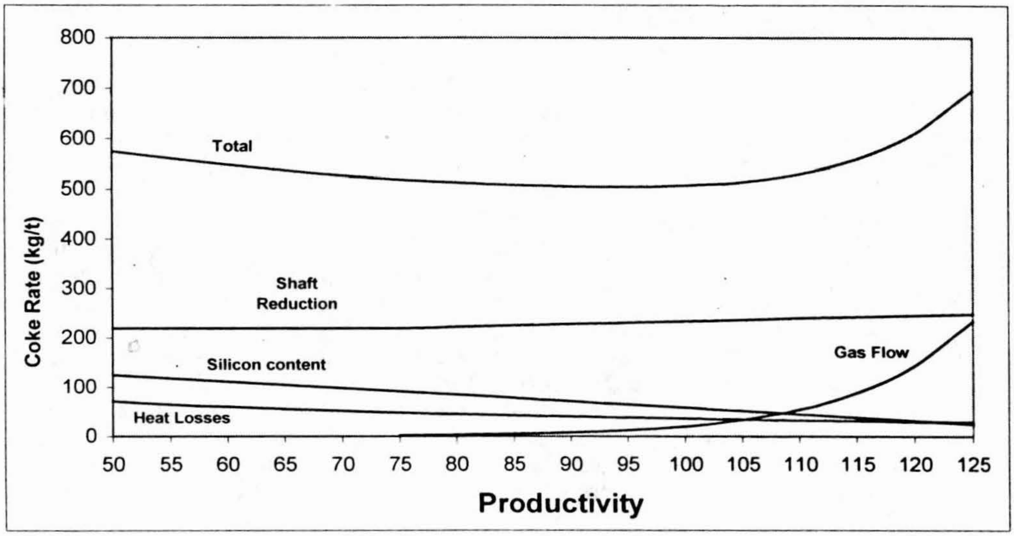

Figure 4 – Coke rate variation with productivity.

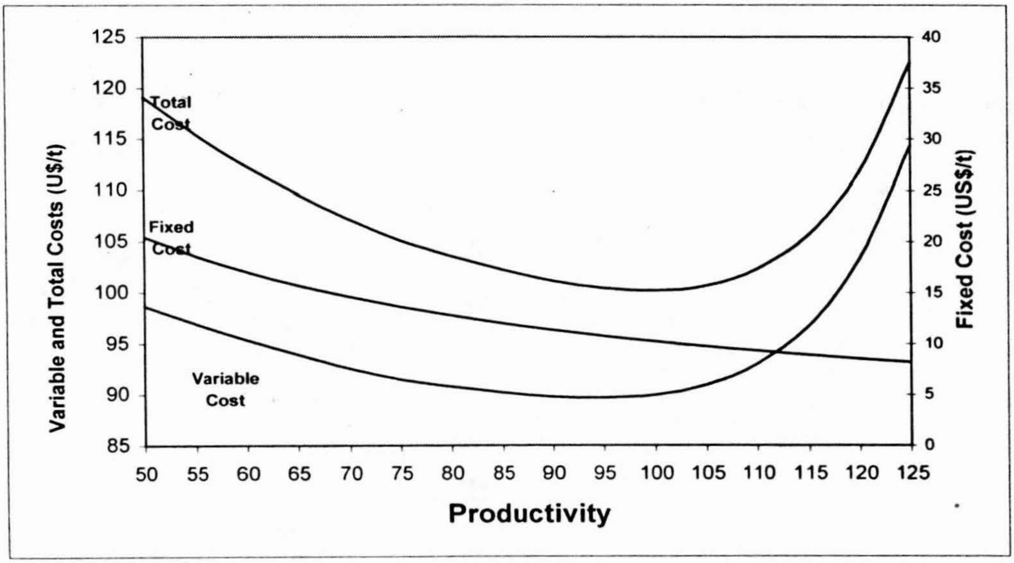

Figure 5 – Cost variation according to the blast furnace productivity.

2.2 Productivity, Operational Practice and Cost

When deciding the type of operation will be used in the blast furnace, mostly the decision is made on a purely technical basis, because it is generally assumed that "if the furnace goes well, the cost will be the lowest". This is not necessarily true, as it will be demonstrated.

For example, Figure 4 shows that above certain productivity, due to the high gas volume, the coke rate starts to increase. A common precaution used in this situation, in order to decrease the gas volume, is to inject oxygen. The oxygen injected will substitute the oxygen contained in the air, and the gas volume decreases because of less nitrogen is introduced in the furnace. Assuming that this operation in fact will solve the gas flow problem, and the amount of coke due to it will not be considered in Figure 4, the cost relative to the coke will be reduced. However, the oxygen cost has also to be considered. Supposing that above the relative productivity of 100 (when the gas flow problem starts to appear) this operational practice is applied. Figure 6 shows the results. It can be seen that, although the oxygen injection technically was the correct action, because it permits to obtain higher productivity, economically it will be a disaster.

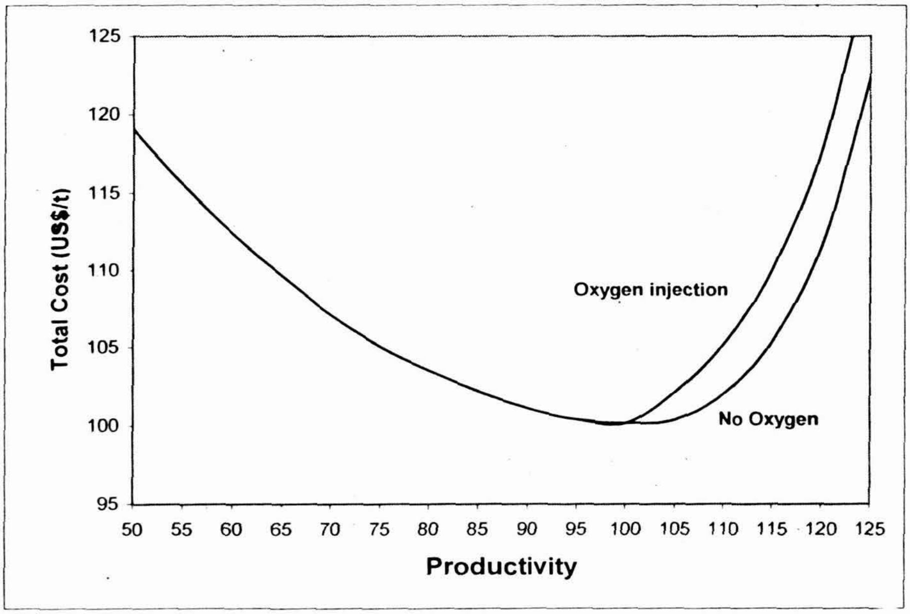

Figure 6 – Cost variation with and without oxygen injection

As in the example above, many technologies are used to overcome the operational problems that happen when high productivity in the blast furnace is desired (better quality raw materials, top pressure, charge distributor, etc.). However, the most important is to evaluate the cost to obtain such high levels of production and to obtain, at the end, financial profit in the operation.

3 CONCLUSION

In the recent years, to obtain high productivity in the blast furnace is an imperative task in order to reduce production cost. However, the cost structure in the blast furnace, where coke represents most of the variable cost and the coke rate depends strongly on the production level, special attention has to be given when choosing the hot metal production level. Different of others processes, where high production levels result in dilution of the fixed cost and, consequently, in lower final cost, in the blast furnace there is an optimal point.

By the other side, to obtain high output level in the blast furnace, many technologies are used to overcome the operational problems arising from such type of operation. In using these technologies, the blast furnace operator must be aware that the final objective is not the productivity itself, but the company's profit.

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