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HYDROGEN ALTERNATIVE ROUTE FOR THE REDUCTION OF IRON ORE IN BRAZIL

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Abstract. *Brazil has decreased the utilization of wood under the form of either charcoal or fuel wood to about 10% of its energy consumption (year 2000). The same is not true for the Brazilian Amazonia where there is a growing demand of charcoal for the production of pig iron in the Greater Carajas Program (PGC) region . The objective of the present study is to verify the feasibility of using electrolytic hydrogen instead of charcoal for the direct reduction of iron ore in that region. Techno, economic and environmental aspects are considered. This study can be beneficial to Brazil in general and Amazonia in particular since natural resources might be preserved and environmental pollution avoided.*

Keywords. *Amazonia; Hydrogen Iron Ore Reduction; Natural Preservation.*

1. Introduction

Brazil, in the year 2000, produced 27.72 million ton of pig iron. From that total 20.32 million ton were produced through the use of coal and 7.39 million ton were produced through the use of charcoal. The yearly produced pig iron and consumed charcoal by the Brazilian blast furnaces as published by Abracave - Brazilian Association of Charcoal (Abracave, 2001) points an average of 1.1 ton charcoal for the production of 1 ton of pig iron. In the year 1998, the independent pig iron producers consumed 6.4 million ton of charcoal, being 1.4 million ton from that total spent in the Greater Carajas Program (eastern Amazonia). At years 99 and 2000, the Greater Carajas Program consumed 1.6 and 1.4 million ton of charcoal, respectively. In average the Greater Carajas Program is producing yearly 1 million ton of pig iron. It is known to almost every sector involved in the Greater Carajas Program that a 100% reforested charcoal based metallurgy is not economically viable and that only a part of the produced charcoal in PGC is reforested. If environmental costs due to forest destruction were to be considered the charcoal would be elevated in about USD 30 each ton in its price.

The pig iron production in the state of Minas Gerais (historically the biggest pig iron producer in Brazil) depleted practically all of its natural forest and Minas started importing charcoal from other states such as Goias and Mato Grosso do Sul. For example, the statistics of Abracave (2001) shows that to the year 94, Minas Gerais consumed 80% of the charcoal produced in Brazil and other non mentioned states consumed 12%. At the year 2000, Minas consumed 33% (5.71 million ton), the Greater Carajas Program 16% (1.44 million ton) and other non mentioned states 52% (9.14 million ton). The significant participation of other states in the charcoal production probably is based on native wood and most of the remaining native forests of Brazil is in the Amazonia.

If the programmed production of pig iron to the next years is maintained, the native forests in the area of the Greater Carajas Program will be exhausted in no more than two or three decades and the charcoal based metallurgy in that region will be non viable.

The present article highlights an alternative route for the production of iron in the Greater Carajas Program not based on charcoal and which in the near future will be the only economic and environmental sound solution to that region (De Lima, 1991; De Lima et all, 1992 and De Lima et all, 1999). The solution is the hydrogen direct reduction of iron ore which will be subsequently detailed.

2. Hydrogen produced iron in the eastern Amazonia

The here envisaged proposal is to produce sponge iron through the direct reduction of iron ore using electrolytic hydrogen. As stressed in a World Bank report drafted in 1998: "…where technically and economically feasible, direct reduction of iron ore for the manufacture of iron and steel is preferred because it does not require coke manufacturing and has fewer environmental impacts". In other document J. Feinman (1999), President of the J. Feinman and Associates Inc., affirms that "direct reduction processes are favored in those locations with abundant reserves of inexpensive natural gas, non-coking coals and/or hydroelectric power, and that have access to suitable iron ores or agglomerates." The region of the Greater Carajas Program (PGC) looks like the best location in the world to be implanted a program of direct reduction of iron ore because: a) there is an immense reserve of iron ore; b) there is available hydroelectricity in the Tucuruí power plant; c) plentiful condition to produce electrolytic hydrogen; and d) there is interest of the global community to preserve the rain forest.

Hydrogen can be used in almost every application in which fossil fuels or wood are used today and it can be also used successfully for the reduction of iron ore instead of coal or charcoal. Hydrogen application for the reduction of iron ore has many advantages such as: it does not create significant pollution; the overall heat consumption is less than in coke or charcoal fueled blast furnaces; the produced sponge iron has low level of impurities.

It is proposed herein to use part of the available hydroelectricity generated in the Tucuruí hydropower plant for the production of the hydrogen that will be necessary for the production of sponge iron through direct reduction of iron ore. Considering that off-peak electricity should be very cheap (from 0.01 to USD 0.03 per KWh) hydrogen would be produced in a price estimated to USD l0/GJ (USD 0.l/Nm^3). The production of hydrogen from water by electrolysis is a fundamentally simple process and the technology is already developed and mature. All over the world nowadays there are several existing large electrolysis installations producing hydrogen and oxygen. Electrolyzers are the main part of the electrolysis plant but other elements are also required such as a direct-current supply, a feed-water supply, electrolyte circulation, gas separation and purification, cooling, inert gas supply, process control and a power supply for auxiliary plants. In average one Nm^3 of hydrogen can be produced with 4.4 KWh of electricity.

There are many developed and under research processes of iron ore reduction which can be adapted to hydrogen utilization. As highlighted by Zervas et al. (1996) over the past three decades there have been two separate lines of development in primary iron-making technology . The mainstream has centered on the blast furnace, which still remains the principal process unit for iron production throughout the world. The dominant alternative technologies are based on direct reduction and smelting which emerged during the late 1960's and early 1970's and in which iron oxide feedstock's are reduced to metallic iron by reducing gases, often at temperatures below the melting point of iron itself, and by this way avoiding the use of coke or charcoal. Direct reduction processes convert iron ore under the form of fines, pellets, sinter, etc., into sponge iron and it can be divided into two classes according to the fuel used: natural gas or coal. The natural gas based processes are the most easily adaptable to hydrogen utilization. In fact, the use of hydrogen as a reductant gas in the DR route will even simplify the direct reduction process since it makes the reducing gas production unit (the gas reformer where the natural gas is reformed to produce CO and H2) unnecessary (Tarnay,1984).

Among various commercially available reformed natural gas direct reduction (DR) processes the most known are: Midrex DR process; HYL DR process; Armco DR process; Purofer DR process; Fior DR process; and, Reduction Shaft DR process (Davis e all, 1982). In average any DR process require approximately 10 to 12 GJ for the production of one ton of sponge iron. Exception is made to the fluid bed FIOR process requiring 15 GJ. Once adapted to hydrogen the difference among those processes would be the consumption of hydrogen, the consumption of electric energy, investment cost and technological improvements. For example, in average the Midrex process would require 110 KWh of electric energy and 625 Nm^3 of electrolytic hydrogen for the production of 1 ton of sponge iron. The HYL process 90 KWh and 750 Nm^3 respectively. The Armco process 20 KWh and 700 Nm^3 and the Purofer process, 120 KWh and 750 Nm^3, respectively. The reduction Shaft process would require 1,100 KWh of electric energy and about 535 Nm^3 of hydrogen for the production of 1 ton of sponge iron.

The cost of production of 1 ton of sponge iron through the Midrex process, for example, will be about USD 115. That cost when broken up will be composed of USD 14.2 for 1.5 ton of iron ore, USD 62.5 for 625 Nm^3 of electrolytic hydrogen, USD 3.3 for electric energy (USD 0.03/ KWh), USD 4.00 for labor, USD 4.3 for cost of maintenance, USD 3.55 for other minerals supply, USD 3.2 for depreciation, USD 4.5 for administrative costs, USD 2.5 for other costs and USD 12.8 for transportation. In the year 2001, as published by Abracave (2001), the Brazilian Association of Charcoal, the average price of the charcoal produced pig iron was of USD 103.00 each ton, considering USD 42.00 for the necessary charcoal. Until July 2002, pig iron recovered price to an average of USD 113.00 each ton. If for the price of pig iron the environmental cost is considered, without doubt the hydrogen direct reduced iron is potentially competitive.

The environmental benefits for adopting the DR process will be the reduction in the emission of atmospheric pollutants and the eventual preservation of the brazilian rain forest.

3. Conclusion

The program of "development" of the Brazilian eastern Amazonia seems to be an irreversible process. Many charcoal fired pig iron projects were implemented or are under implementation on that region, previewing an increased consumption of wood under the form of charcoal. The depletion of natural resources will be mitigated if a program of hydrogen direct reduction of iron ore is implemented on the Greater Carajas Program. This technology is just about to be economically competitive and for sure is already environmentally sound.

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