THE GROWING IMPORTANCE OF PELLETIZING FOR IRON ORE MINING AND IRON PRODUCTION [1]

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Abstract
In the last years, pelletizing has been playing an important role in iron ore mining and in iron production (iron making and direct reduction). Some factors have contributed to this fact as follows: the depletion of high grade iron ore reserves, the great Chinese iron ore demand, the accelerated growth of direct reduction, the better performance of pellets as burden of the reduction reactors, environmental restrictions in steelmaking, etc. In order to comply with blast furnace and direct reduction demand, existing pelletizing plants are being improved and new projects are under evaluation and or erection. Pellet production will increase so fast in coming years. At the end of 2007, the amount was near 370 Mt. In 2015, is estimated some over 500 Mt. Following the trend of other industrial activities, pelletizing is being affected by price increase of power, oil, steel and commodities. Capital and Operational costs (CAPEX and OPEX) are impacting so much the profitability of pelletizing business, in a stand alone basis analysis. This paper gives a brief evaluation of these themes related to iron ore pelletizing.
Key words: Pelletizing; Iron ore; Iron making; Direct reduction.

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1 INTRODUCTION

Pelletizing has been producing pellets for blast furnaces and direct reduction use, since the 1950's. It started taking advantage of low grade taconite, a magnetite ore, in United States, by the development of the former and obsolete technology known as Shaft Furnace (SF). By the years, two other processes came on stream bringing more capacity, better performance and efficiency on this activity. One of them, Traveling Grate (TG), was proven to be used for any kind of iron ore, hematite, magnetite and hydrated ones, sharing more than 60% of total capacity ever built in the world.(1) The other, Grate Kiln or Rotary Kiln (RK), was more indicated to treat magnetite ores, showing some limitations for hematite and or hydrated ones. Its share is around 30%.

For years, Lump ore was the main material in the burden of blast furnaces. With the depletion and or degradation of reserves of hard hematite ores, the agglomeration technologies (sintering first and after pelletizing) played an important role, making available sinter and pellets as feedstock for blast furnaces and direct reduction reactors. Particularly, in Brazil, the reserves of iron ores in the state of Minas Gerais contain great amounts of itabirites (iron banded formations, silica-hematite). Because of this, the ore needs more intensive treatment with cost increasing and there is more generation of ultra-fines like pellet feed. When analyzing the greenfield projects which are being developed at this moment, one can see that many of them will generate 100% of pellet feed.The pelletizing is the available technology to take care of such fines. Other facts influencing the expansion of pelletizing are related to favorable environmental issues and better performance of pellets in blast furnaces and direct reduction reactors, etc.

For the mining industry, pelletizing became as the solution to treat the increasing amount of ultra-fines produced in iron ore exploitation and concentration steps. For iron making and steelmaking, it gave alternative product to substitute scarce lump and to improve performance of blast furnace and direct reduction.

2 SOME IMPORTANT FIGURES OF PELLETIZING PROCESSES

There are two pelletizing technologies which produce more than 95% of pellets in the world:

- Traveling Grate (TG): with proven plant capacity up to 7.5 Mt/year/furnace, and
- Rotary Kiln (RK): with proven plant capacity up to 5.0 Mt/year/furnace.

The former and obsolete process known as Shaft Furnace (SF) with capacity up to 0,5 Mt/year/reactor remains in activity basically in China, but step by step it will disappear based on its lower performance and higher operating costs.

Independently on pelletizing technology, it's necessary to develop 3 main stages to produce pellets, as can be seen in Figure 1:

2.1 Stage 1: Ore Preparation

Iron ore preparation means to treat the ore in order to get the standard fineness which is necessary to form the balls. This fineness is dependent on the ore characteristics. In general, surface area in the range of 1700-2200 cm2/g and size passing in 0,074 mm are demanded for good balling. To get these figures, fragmentation is needed. Natural pellet feed, normally, is not ready to be pelletized. It is coarser than that. Dry or wet grinding in ball mills is the main process used in this

stage. Grinding is intensive in energy, operational and capital costs (OPEX and CAPEX). Ore preparation, including all the other complementary equipments, could represent some like 30-35% of CAPEX and 25-30% of OPEX of a pelletizing plant with the basic 3 stages. It is important to mention that if the grinding is wet filtering is included in this stage 1. If it is dry, drying system and complex dry classification equipment are included.
For pelletizing plant which hasn't this stage 1 in its process battery limits, it is understood that it will receive the iron ore already prepared by the supplier (mining). This means that the plant will receive a *more added-value ore,* in face of avoiding expenses in capital and operational costs related to grinding.

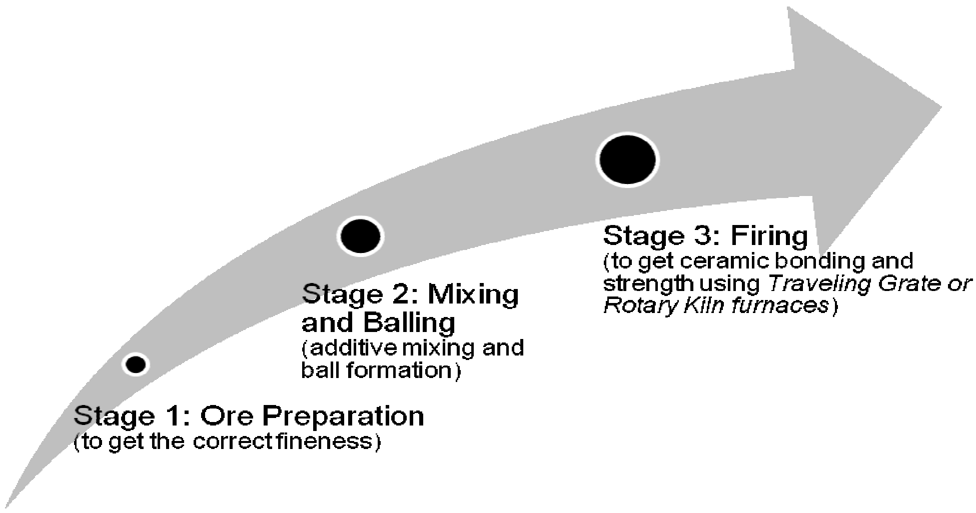

Figure 1 – The 3 basic stages of any Pelletizing Process

2.2 Stage 2: Mixing and Balling

Prior to the formation of green pellets, water is added to the prepared iron ore, to correct the moisture content to approximately 9%. Then the ore is mixed with small amounts of binding agents such as bentonite and fluxes like limestone, olivine and dolomite, in order to adjust de basicity. These additives give the pellets the prerequisite chemical, physical and metallurgical properties required for further processing in blast furnaces and direct reduction. Mixing takes place in continuously operating drum or pan-type mixers. On an industrial scale, green pellets are formed either in pelletizing discs or drums. Pelletizing discs need only a single process step to form pellets. Green pellet size can be precisely adjusted by varying the disc or inclination, circumferential speed, feed or water addition rates. CAPEX and OPEX (excluding additives) in this area are not so relevant, compared to the other 2 stages.

3.3 Stage 3: Firing

This is the *core stage* in any pelletizing process. Here, CAPEX and OPEX are so important. Respectively, could represent 40-45% and 60-65% of a plant having the 3 basic stages in its flowsheet. It is clear that this cost partition depends on the place in which the plant is installed, the raw material, power and oil/gas prices, etc. *Traveling Grate and Rotary Kiln* furnaces are used to fire or indurate the green pellets coming from balling. To get the enough pellet strength and metallurgical properties, heat, temperature (up to 1350°C) and residence time have to be strictly controlled. Travelling Grate is a single tubular furnace shape, with an inside movable grate, as

seen in Figure 2. All the firing steps are done in this equipment. By the other side, rotary kiln has 3 connected reactors, where the firing takes place: movable grate,rotary furnace, and annular cooler. Many plants of both processes were built in different places of the world. However, the experience and expertise of users and licensees of these technologies have been indicating that RK has limitations to treat hematite and hydrated ores. It is more indicated for magnetite type or mixture hematite-magnetite.(1) The main reason for this is that after drying and pre-heating the pellets in the RK grate, the soft material has to be moved or transferred to the second reactor, the rotary furnace. Then, fines can be generated lowering the process efficiency. Magnetite green pellets have different behavior inside the furnace. In pre-heating zone, there are oxidation and re-crystallization of magnetite grains creating bonding and enough strength for safe related transfer to RK. More recent experience with hematite green pellets in RK showed that it was necessary to increase so much the temperatures in pre-heating zone, to compensate the lack of strength of hematite pre-heated pellets. RK and TG furnaces have the same magnitude of CAPEX, considering similar annual capacity. As TG has proven bigger units, with capacity up to 7.5 Mt/year/furnace against 5.0 Mt/year/furnace of RK, TG is taking advantage of lower fixed cost unit due to this enlargement. Recently, the TG technology supplier has announced its intention on development of units with capacity near 10 Mt/year in a single furnace.
Actually, Traveling Grate process shares 2/3 of total pelletizing capacity in the world.(1,3) Since the beginning of pelletizing, many plants of TG, RK and SF were built worldwide, to process different types of iron ores, like magnetite, hematite, limonite, ghoetite, mixture of them, etc. Considering the total pelletizing capacity ever built, the following statistics could be developed:

Total capacity ever built: 449 Mt/year
- Share of Traveling Grate - TG: 277 Mt/year (62%)
- Share of Rotary Kiln - RK: 138 Mt/year (31%)
- Share of Shaft Furnace - SF: 31 Mt/year (7%)
- Share of other obsolete technologies - OT: 3 Mt/year (1%)

Considering the nature of iron ores treated by these technologies and the same statistical basis, it is possible to understand that Rotary Kiln has some limitations to process 100% of hematite ores. Figure 3 shows the total capacity installed by the different technologies as a function of the kind of iron ore treated, since the beginning of pelletizing activities.

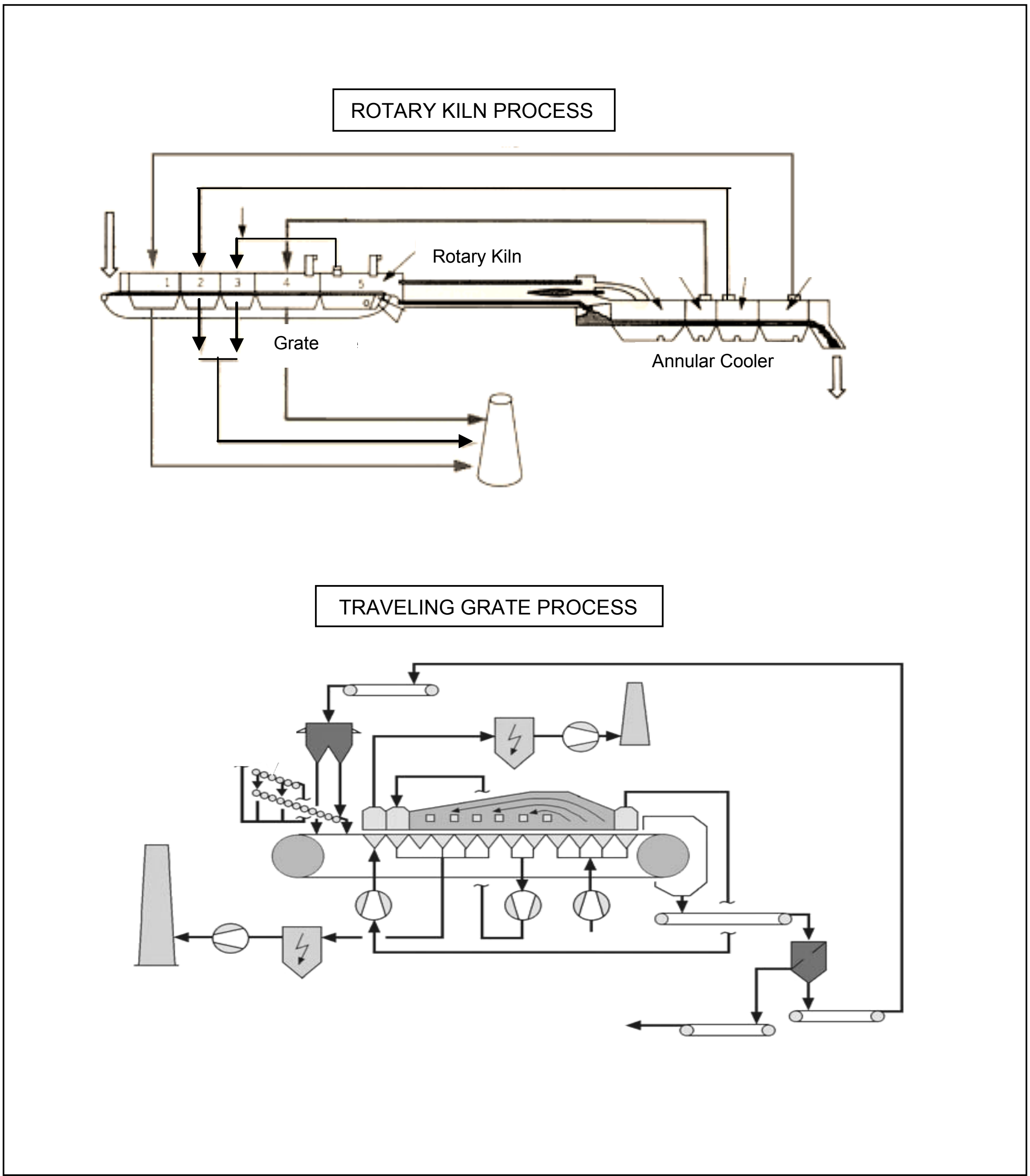

Figure 2 – Basic diagrams of Rotary Kiln and Traveling Grate Furnaces[2,3]

Nowadays, total world capacity of pelletizing is around 380 Mt/year of pellets to be used as feedstock for blast furnace and direct reduction.
When studying the feasibility of pelletizing projects, particular attention must to be paid on stage 3. There, it will be spent most of CAPEX and also most of the future and permanent OPEX. The profitability will depend on the performance of the plant and stage 3 represents the core of the pelletizing technology.

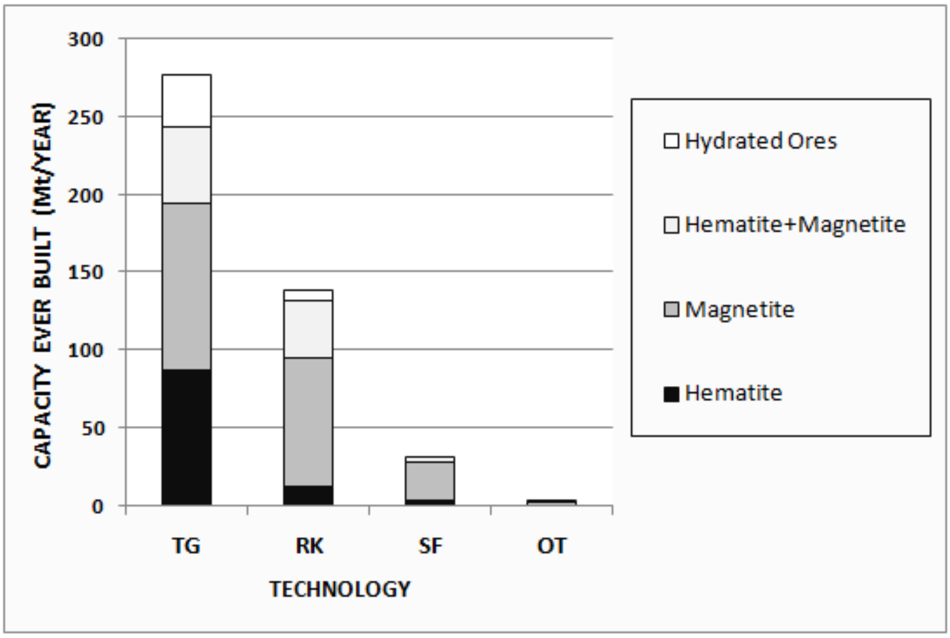

Figure 3 – Total pelletizing capacity ever built vs. type of ore vs. technology.[1, 3]

Pelletizing is the most engineered agglomeration technology. Pellets present the best chemical, physical and metallurgical properties compared to other agglomerates (sinter, cold bonded products, briquettes, etc.). They can be handled and transported at long distances without fines generation. Chemical composition can be adjusted in a very wide range as shown in Figure 4.[4] In general, SiO2 can be varied from 0.8 to 8% and basicity from 0,1 to 2.0. Iron content is in the range of 58-68%. Concerning to direct reduction, it requests the richest ores with no deleterious elements like P, S, Ti, V, etc. This means pellets with higher iron content (Fe > 67%), as can be seen in the top of figure 4. Blast furnace pellets are classified in 3 categories as a function of basicity: acid, fluxed and super-fluxed ones. In the same figure, these 3 fields are highlighted in the bottom region. Fluxed and super-fluxed pellets have better metallurgical properties for both blast furnace and direct reduction use. Super-fluxed type requests bigger additions of basic fluxes like limestone, dolomite, etc, with operational cost increase. In this condition, the iron content drops as the basicity increases. As well known in the iron ore market, the price of pellet is fixed as a function of its Fe %. This practice doesn't take into consideration the added-value by higher basicities and doesn't incentive the development of super-fluxed material. It has higher production cost and lower price (% Fe); in other words, lower margin. Producers and consumers have a long way to evaluate this subject and to change some market rules. It's imperative to introduce the value-in-use concept during negotiations to advance in the field of super-fluxed pellets.

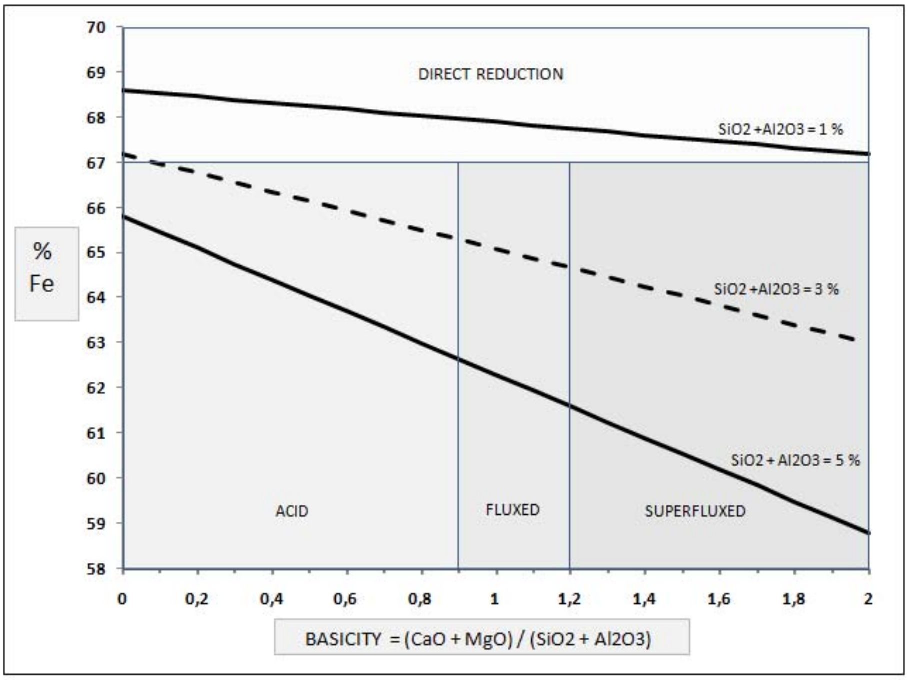

Figure 4 – Chemical parameters of pellets: Fe% vs. Basicity vs. $SiO_2+Al_2O_3$.(4)

3 THE REASONS FOR PELLETIZING GROWTH

Pelletizing is growing in a fast way. There are many reasons supporting this trend. The main ones could be listed as follows:

- ✓ Depletion or degradation of iron ore reserves.
- ✓ Expansion of direct reduction.
- ✓ Environmental restrictions on sintering in developed countries.
- ✓ Improved performance of blast furnace and direct reduction when using higher amount of pellets.
- ✓ The China effect.

The reserves of iron ore in the world are under degradation in terms of hard hematite and Fe contents. In Brazil, for example, the mines situated in the state of Minas Gerais are exploiting run of mine with increasing proportion of poor itabirites, as shown in Figure 5. This fact is impacting mining and treatment cost, increasing the production of ultra-fines like pellet feed as well as decreasing the production of lump ores. Pelletizing is the only available technology to treat the great amounts of pellet feed. It will contribute to improve the overall balance of mining operation. Pellet feed can't be used directly in iron making or direct reduction. Also, it has very limited use in sintering process. Many new technologies, with focus on direct use of pellet feed for iron making, are being studied. In this sense, it could be cited: Dios, Finmet, Iron Carbide, Circofer, Circored, Tecnored, Hismelt, etc. Till this moment, none of them was proven for commercial purpose. Another effect of changes in quality of iron ore reserves is lump ore production and availability. Not only in Brasil, but also in Australia, the production of lump ore will continue to decrease in volume. At the same time, quality degradation is expected in terms of physical and chemical characteristics (deleterious elements like: Al_2O_3, P, Na, K, etc.). For years, lump ore was the main ferrous material in the burden of blast furnaces. Nowadays, it continues to play an important role in iron making, sharing in general up to 20% of big blast furnace burden. Smaller ones, like charcoal blast furnaces in Brazil, have been using 100% of lump. Pellets will bring solution for lump scarceness, as a real substitute.

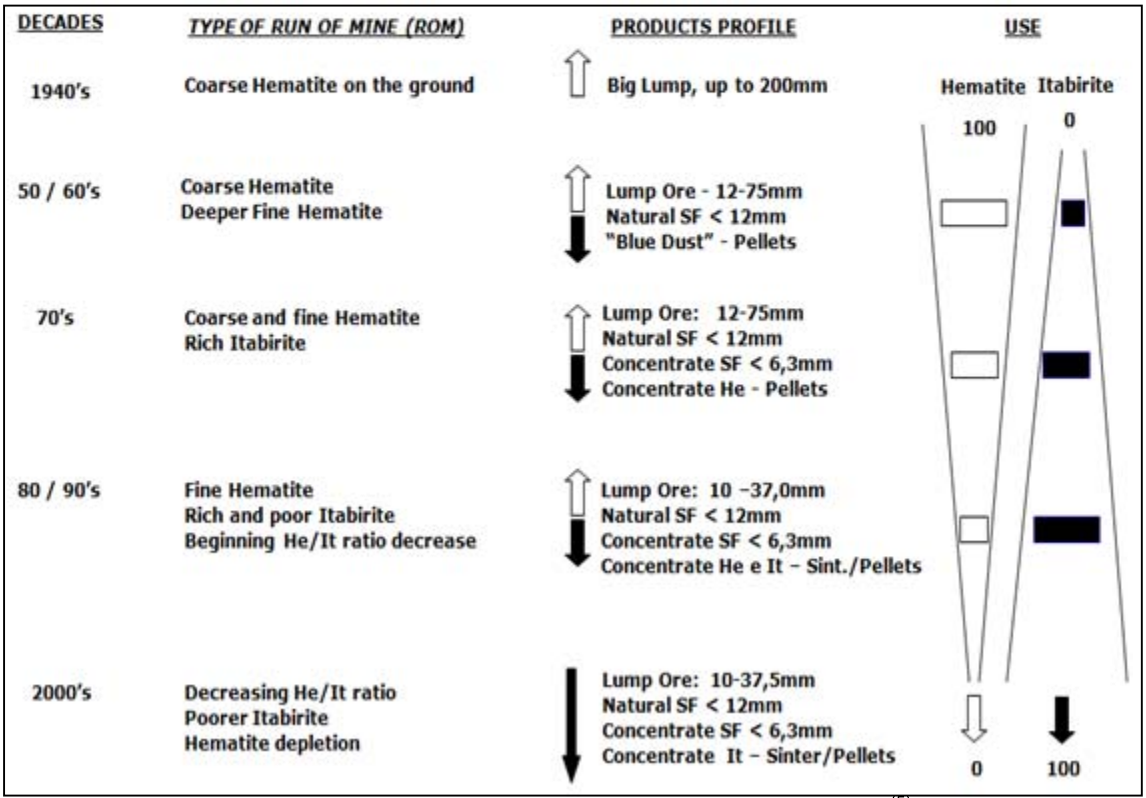

Figure 5 – Quality degradation of iron ore reserves.[5]

Direct reduction makes use of almost 100% of pellets in the burden. There is no more high quality lump available for this technology which demands higher Fe and lower impurity contents. Any increase in DRI or HBI production means equivalent increase in pellet demand. In the last years, the world capacity of direct reduction is growing and reaching the level of 70 Mt/year (equivalent demand of around 100 Mt pellets). Middle east, Africa and Southeast Asia, based on their big natural gas reserves, are developing aggressive plan to put on stream new projects and new capacity of direct reduction. Table 1 shows the new plants which are entering into operation. Additional demand of 20 Mt/year of direct reduction pellets will incentive huge investments in iron ore mining and pelletizing.
Sintering is an agglomeration process responsible for the majority of iron units entering the blast furnace. The product, sinter, is the basic burden material in iron making in most developed countries like Japan, European countries, etc., where environmental laws impose hard restrictions to sintering emissions. Due to this fact, no new sintering capacity will be put on stream in these areas. Some steel mills located in Europe have built new blast furnaces without sintering plants. To increase steel production via blast furnace/BOF route, the related steel mills would need more quantity of pellets.

Table 1 – Development of direct reduction – New capacity of DRI/HBI.[6]

Plant	Location	Capacity (Mt/year)	Technology	Start up
Mobarakeh	Mobarakeh, Iran	0.80	Midrex	2006
Al-Tuwairqi	Dammam, Saudi Arabia	1.00	Midrex	2007
Hadeed E	Al-Jubail, Saudi Arabia	1.76	Midrex	2007
Lebedinsky II	Gubkin, Russia	1.40	Midrex	2007
The Lion Group	Banting, Malaysia	1.54	Midrex	2007
Qasco II	Mesaieed, Qatar	1.50	Midrex	2007
Shadeed	Sohar, Oman	1,50	Midrex	2008
Tuwairqi	Karachi, Paquistan	1,28	Midrex	2008
General Holding	Abu Dhabi, UAE	1,60	HYL	2008
Total		12,38 (equivalent to 20 Mt/year of pellets)		

Pellets improve performance of blast furnaces. In mixture with lump and sinter, it's possible to gain productivity and reduce coke/slag rates. Figure 6 was built considering operational data of many steel mills. [5]. One can see the benefit of pellet use in blast furnace, in combination with sinter and lump ore.

In Brazil, Arcelor Mittal – Tubarão, in Vitória ES, is taking advantage of these points. It started up a new blast furnace without equivalent new sintering capacity. The 3 blast furnaces of the company are running at high level of pellets in the burden. Previously, the use o pellets was around 20-25%. Now, it was increased to the level of 40%.

China increased enormously steel production, in the last 5 years. The iron ore demand is growing very fast and mining companies are investing huge amounts of money to comply with market needs. Chinese steel mills made option to implement pelletizing capacity to produce most of their pellet needs. Their plans are to increase the use of pellets in blast furnaces from 5-10% to 15-20%, in coming years. Avoiding buying pellets they will need to import concentrate to feed the pelletizing plants. The Steel Mills will remain importing about 20-30 % of pellet consumption, which will represent some like 30-40 Mt/year, in 2015.

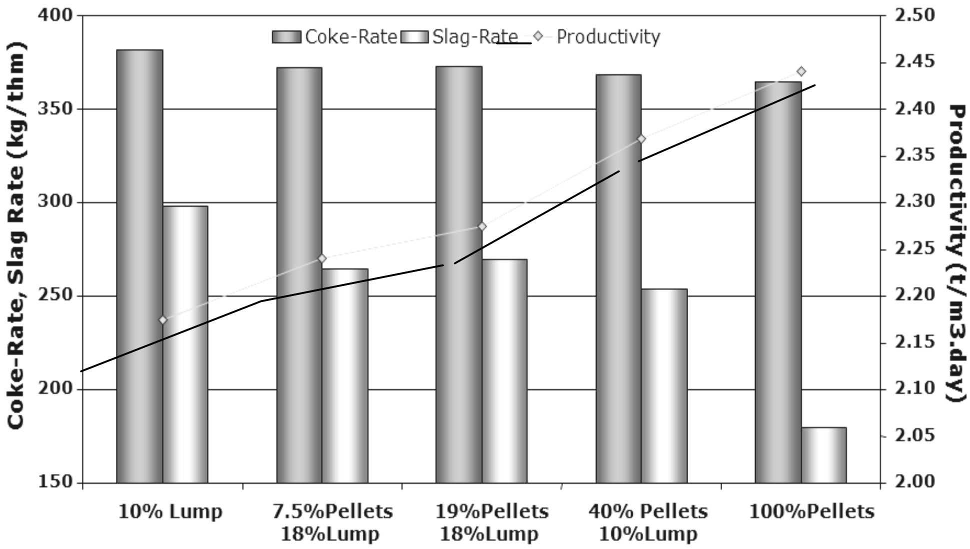

Figure 6 – Impact of pellet use on performance of blast furnace (with PCI).(5)

4 OUTLOOK FOR THE FUTURE

World pellet production has been growing, step by step, since 2002.(7) Many institutes and consulting companies predict that this trend will continue, at least up to 2015. Figure 7 shows the evolution of pellet consumption in the world as well as the estimates for the near future. The total consumption of pellets will increase and overpass 500 Mt in 2015. Part of this demand will be covered by captive production in steel mills, other part will be supplied regionally by mining companies and the rest will go to the seaborne trade. Nowadays, the handled volume in the seaborne is around 100 Mt of pellets annually. In 2015, this quantity could reach 150 Mt/year, representing an increase of 50 Mt/year. Considering the expansion of direct reduction, it is expected that great amount of seaborne growth will be of pellets for direct reduction use.

To comply with these market needs, mining companies are planning investments in new pelletizing capacity in different places of the world. Table 2 presents the data concerning to this subject. World existing pelletizing capacity is close to 380 Mt/year of pellets. New plants are being planned for starting operation up to 2015. There will be an increase in pelletizing capacity around 150 Mt/year. In 2015, total capacity will also surpass 500 Mt/year of pellets. The comparison between the estimated consumption of pellets in the coming years and the evolution of world pelletizing capacity suggests that the supply-demand figures will stay in a very tight equilibrium.

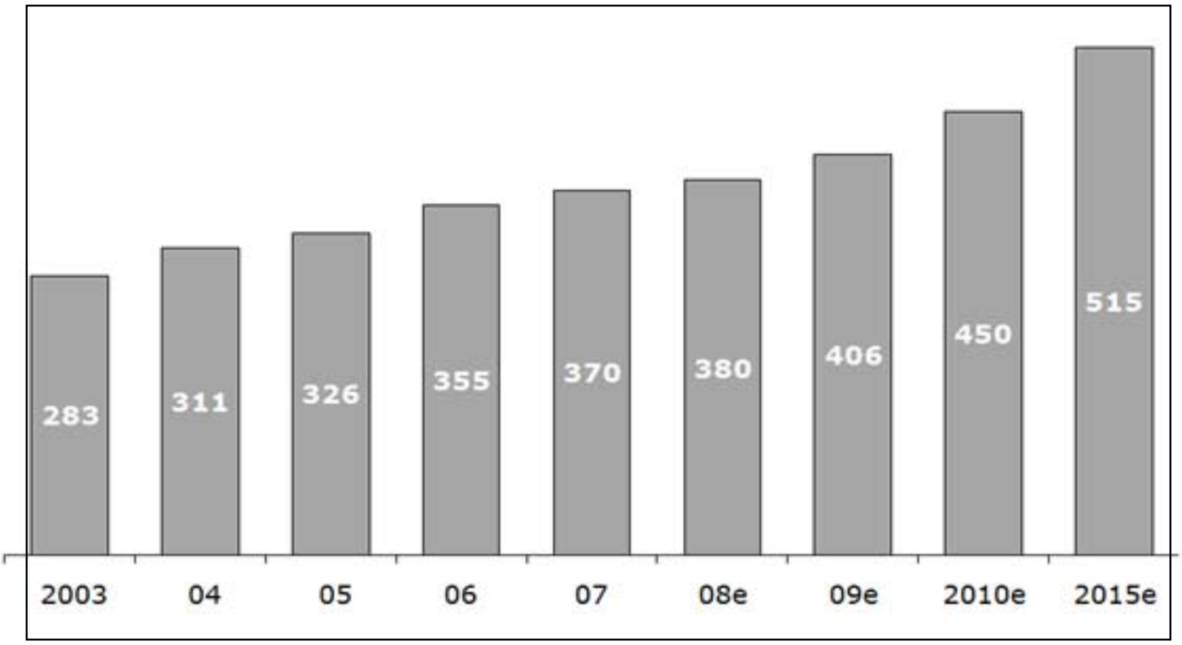

Figure 7 – Estimation for world pellet consumption – Mt/year.[4,7]

5 CONCLUSION

The difference between pelletizing technologies is only in the firing stage. This step is the most intensive in capital and operational costs. In this sense, project leaders must to be paying more attention on technical evaluation of the different options. Iron ores have identity. Their properties depend on the geological formation and their behavior varies in a very wide range. Taking this information into account, it would be very important for decision making to perform pilot tests with the ores and collect operational data from existing industrial plants.

Pelletizing of iron ores will play an important role for mining and iron making in the next coming years. For mining because it is the only efficient and proven technology available to treat the growing amounts of pellet feed. For iron making because it is able to bring solution for potential scarceness of lump ores. Furthermore, pellets can substitute sinter and lump in any proportion and improve the performance of blast furnaces and direct reduction reactors.

Pelletizing will grow at least up to 2015, when total world capacity will surpass the level of 500 Mt/year. Estimates on the supply and demand figures suggest that the market will stay verytight.

Table 2 – World pelletizing capacity and expansion projects.(4, 7)

WORLD CAPACITY t x 10^6		
North America		**105,0**
	Canada	30,0
	Mexico	15,0
	United States	60,0
South America		**75,0**
	BRAZIL	55,4
	Chile	5,3
	Peru	3,5
	Venezuela	10,8
Europe		**100,4**
	Netherlands	4,4
	Russia (*)	75,0
	Slovakia	0,5
	Sweden	19,0
	Turkey	1,5
Asia		**92,0**
	Bahrain	4,5
	CHINA	60,0
	India	13,0
	Iran	10,5
	Japan	4,0
Oceania		**4,2**
	Australia	4,2
TOTAL		**376,6**

(*)CIS included

EXPANSION PROJECTS	CAPACITY t x 10^6	START UP
Samarco 3 - Brazil	7,5	2008
Vargem Grande - Brazil	7,5	2008
Vale 3 - Brazil	7,5	2010
MMX Minas Rio - Brazil	7,0	2010
Kiruna 3 - Sweden	5,0	2008
Zuhai - China	1,2	2008
Ying Kou - China	4,0	2008
New Millenium - Canada	15,0	2011
Gol-e-Gohar Mining - Iran	10,0	2008
Sohar Industrial - Oman	9,0	2010
Grange Resources - Malaysia	7,0	2010
Ferrexpo - Ukraine	8,0	2014
China / other projects	65,0	up to 2015

CAPACITY INCREASE (**)	t x 10^6
2008	35,2
2010	48,5
2011	26,0
2014	33,0
2015	11,0
TOTAL CAPACITY INCREASE UP TO 2015:	**153,7**

(**) China/others: distributed between 2009/2015

TOTAL CAPACITY IN 2015: 530,3 Mt/year

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