MICROSTRUCTURE OF IRON ORE PELLETS - ORGANIC AND INORGANIC BINDERS[1]

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Abstract

Pelletization is the standard method of agglomeration used to turn fine fractions of iron ore into an adequate product (pellet) to be fed to the blast furnaces and to the direct reduction reactors, where it will be reduced into pig iron or sponge iron. This study aimed to compare the performance of two different agglomeration binders, inorganic binder (bentonite) and organic binder, in the iron ore pellet microstructure. With this goal it was studied four distinct samples of iron ore concentrate, from four different Brazilian mines. Pellets made in a laboratory pelletizing disc were tested as follows: wet-knock, wet compressive strength, dry compressive strength, shock temperature and thermally treated at 1350ºC. Microstructural analysis of the pellets after the thermal treatment showed the presence of ceramic bridges, as expected when using bentonite as an agglomeration binder. As well, those bridges were not found in the organic bindered pellets. From the obtained results it is possible to conclude that the organic binder, compared to inorganic binder, presents better results.

Key words: Iron ore; Pelletizing; Binder.

MICROESTRUTURA DE PELOTAS DE MINÉRIO DE FERRO - AGLOMERANTES ORGÂNICO E INORGÂNICO -

Resumo

A aglomeração por pelotização é o método padrão aplicado para transformar as frações finas de minério de ferro em um produto adequado (pelota) para alimentação do alto forno e dos fornos de redução direta, onde será transformado em gusa ou ferro esponja. Este estudo visou comparar o desempenho dos diferentes aglomerantes (bentonita e aglomerante orgânico) de uso comercial, na microestrutura das pelotas confeccionadas com concentrado de minério de ferro. Com este objetivo foram estudadas quatro diferentes amostras de concentrados de minério de ferro de diferentes procedências de minas brasileiras. Foram ensaiadas pelotas produzidas em disco de pelotização de laboratório através da rotina de ensaios que incluíram: compressão simples das pelotas úmidas e secas e tratadas termicamente à temperatura de 1350°C, quedas repetidas das pelotas úmidas e ensaios de choque térmico. Quanto à análise microestrutural das pelotas após o tratamento térmico, foram identificadas as pontes cerâmicas características quando do uso da bentonita como aglomerante no caso de todos os concentrados estudados, fato este que não ocorreu quando foi utilizado o aglomerante orgânico. De modo geral, pôde-se concluir que o aglomerante orgânico, em comparação à bentonita, tem o melhor desempenho na obtenção da pelota queimada.

Palavras-chave: Minério de ferro; Pelotização; Aglomerantes.

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1 INTRODUCTION

The pelletization process was brought to Brazil through a partnership between CVRD and IPT – Institute of Technological Research of the State of São Paulo, in the 1970´s, at the former Section of Siderurgical Raw Material, now known as the Environmental and Energetic Technology Center.

The process consists, in its essence, on the formation of wet pellets by rolling fine ore concentrate, previously mixed with additives (limestone, coal) and the binder. The amount of water to be added varies but, according to Lima (1991), it is a fundamental factor in the formation and growth of the pellets, once water creates the superficial tension that keeps the mineral particles cohesive (neutral tension), allowing pellets to be handled. Thought, the neutral tension by itself is not able to maintain the cohesion of particles with high specific weight. Also, the pellet tends to disintegrate when it is heated, because of the large amount of gases generated by the vaporization of water.

Additives are used to prevent such effects, by enhancing the compressive strength of pellets before heating (wet compressive strength), and avoiding their collapse while in the initial stages of heating. Binders must be added to the pelletization mixture to raise the liquid phase viscosity inside the capillary spaces; maintaining the cohesion of “green” pellets; and to improve the compressive strength of the thermally treated pellets, by contributing to the formation of ceramic or iron oxide bridges, or to the scumming of discrete places, during the thermal treatment.

The classic binder for iron ore pelletization is bentonite, that is characterized by its high swelling power, great superficial area, cation exchange capacities around 60 to 170 meq/100g and thixotropy property. Bentonite enhances the resistance of iron ore pellets by the following mechanism: the presence of colloidal material shortens the distance between particles, then raising the intensity of the Van der Waals forces. The deposition of bentonite plates in the point of contact between ore particles also enhances the pellet’s compressive strength. The typical dosage of bentonite as a binder for iron ore pelletization is 0.5 to 0.7% in mass (dry basis).

Binders that did not leave residue after the thermal treatment would be extremely interesting. They would be advantageous for having minimized the quality variations, as they are an industrialized product, and for lowering the dosage to be used, that is around 0.05%.

Several products have been studied, as carboxi-methil-cellulose (CMC), guar gum, hemicellulose, starch acrylate and polyacrylamides, amongst others. Lima (1991) studied the use of CMC as a binder for iron ore pelletization. Previous tests using organic reagents had led to pellets with weak mechanical properties, especially at high temperatures, and with high production costs or great water consumption. These problems were fixed by adding another reagent along with the CMC, such as Sodium Tripoliphosphato (TPP).

Motivated by the excellent indicators for the potential of utilization of the CMC achieved by Lima (1991), Cassola and Chaves (1998) studied binders for iron ore aiming to substitute bentonite. The tests showed that the use of only TPP was more effective in pelletization than the combination of TPP and CMC. This suggested the hypothesis that the truly important event of acquisition of mechanical properties by the pellets is the effect of the additive over the ore particles, that is, the crystallization/cementation of dissolved materials.

All the papers reviewed for this research agree that the effect of the ore+binder mixture comes from two different combined mechanisms: the raise of the solution viscosity and the additive´s dispersive action over the colloidal limonite particles recovering the hematite's ones surface.
This later mechanism is the fundamental one for the process. It provides the interstitial viscosity recquired to maintaing the green pellet stable, and allows the formation of a intergranular iron oxide film. Also, it helps the stability of the fired pellet, without interfering with another agglomeration mechanisms.

2 MATERIALS AND METHODS

The pellets made of iron ore concentrates from four different Brazilian mines, were characterized by mechanical resistance tests and microstructural analysis, in order to evaluate the performance of both organic and inorganic binders for the pelletization process. The iron concentrate samples, as well as the binders used in the tests, were provided by mining companies.
The characterization of the iron ore samples, named Mine A, Mine B, Mine C and Mine D, consisted in:

- moisture content determination:
  by heating to 105ºC until constant weight;
- density determination:
  using the picnometer method;
- determination of oxides content:
  Fe_2O_3, SiO_2, Al_2O_3, CaO, MgO, P_2O_5, MnO and loss on ignition (LOI) contents were determined by X-ray fluorescence and traditional humid way;
- mineralogical analysis:
  X-ray diffraction and observation at polarized optical microscopy determined qualitatively the mineralogical composition of the four samples, as well as the morphological characteristics and possible mineral associations;
- size analysis:
  it was performed by exhaustive wet screening in the 0.149 mm, 0.074 mm, 0.053 mm and 0.037 mm meshes.

The following compositions were used in the pelletization tests, for each iron ore concentrate: pure concentrate, concentrate+bentonite and concentrate+organic binder. The dosage of each binder is shown on Table 1, that presents the optimized values currently used in the industry.

Table 1 – Binder and additive adding.

Binder / Additive	**Adding (%)**	
	Mine A	**Mines B, C and D**
Bentonite	0.400	0.490
Organic Binder	0.035	0.040
NaOH (solution at 50% by wt)	0.020	0.020

A 1.2 m-diameter pelletizing disc, showed in Figure 1, was used for the pelletization tests, at 20 rpm and 46º inclination with the horizontal line. The pellets obtained were screened between 12.05 and 11.0 mm in diameter for the tests.
Then, they were submitted to the wet-knock, the wet compressive strength and the dry compressive strength tests. Some pellets were shocked temperature at 300ºC, 500ºC, 700ºC and 900ºC, tested for number of fractures and/or explosions, and for compressive

strength. Finally, some pellets were thermally treated at 1350ºC for 10 minutes, in a muffle furnace; those were compressive strength tested and analyzed by scanning electronic microscopy.

Figure 1 – Pelletizing disc

3 RESULTS AND DISCUSSION

Characterization tests on the iron ore concentrate samples pointed out that:

a) they contain mainly hematite, goethite and magnetite. Hematite occurs in the compact (or lamellar) martitic and porous types, with goethite filling some pores. Also free goethite (intragranular and intergranular) is present in samples Mine A, Mine B and Mine C;
b) Mine B concentrate is the coarser one, with 31% mass retained in the 37 μm mesh. Mines B, A and C concentrates has, respectively, 23%, 19% and 19% mass retained in the same mesh;
c) the contents of Fe_2O_3 in each concentrate are very similar. The highest value is 97.7%. in sample Mine B;
d) the highest content of SiO_2 are in Mine A (0.62%) and Mine B (0.37%) concentrates. The Al_2O_3 content ranges from 0.4 to 0.6% in the samples;
e) the P_2O_5, MnO, MgO and CaO contents are very low, < 0.1%, except for the Mine C (0.25% of CaO) and Mine B (0.31% MnO) concentrates;
f) moisture content of Mine B, C and D samples were inferior to the recommended for pelletization tests, that is in the 10-11% range; it was fixed by adding water before the addition of binders;
g) real density values measured for all iron ore samples were very close, varying from 4.3 to 4.6 g/cm³.

Table 2 presents the results of the tests conducted on the pellets, sorted by sample and type of binder used (organic or bentonite).

Table 2 – Comparison of binder performance for different concentrates

tests		wet–knock test		compressive strength (kgf/pel) wet		dry		300°C		500°C		700°C		900°C		1350°C	
binder*		B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O
concentrate	Mine A	4.3	4.2	1.5	1.2	4.4	3.7	3.5	2.5	2.5	0.8	2.5	0.9	3.0	2.6	142.8	174.5
	Mine B	4.7	5.6	0.7	1.1	4.4	2.9	2.8	2.3	4.3	0.6	3.7	0.8	4.1	2.4	119.9	196.7
	Mine C	6.1	4.4	0.8	1.4	2.7	2.0	2.2	1.9	2.2	0.9	2.9	0.8	3.1	2.2	435.5	469.7
	Mine D	3.4	2.7	0.8	0.7	3.9	3.3	2.7	3.2	2.0	0.9	3.6	1.0	3.9	1.4	185.4	190.3

B (bentonite), O (organic)

Results obtained suggests that bentonite presents better performance in pelletization the different iron ore concentrates studied, specially for thermal shock results. That is due to the fact that at those temperatures occurs the hardening of the bentonite components.

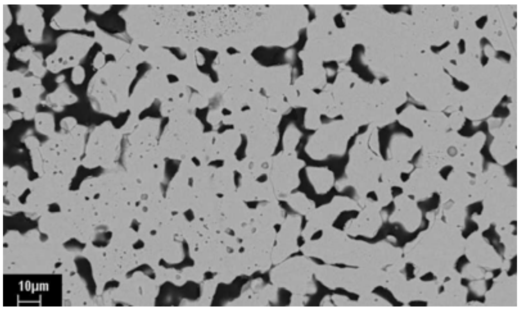
Figures 2 to 4 present the photomicrographies of pellets obtained under different conditions, for each concentrate, after thermal treatment at 1350°C for 10 minutes.

Pellets shown in figure 2 were obtained without any binders. Pellets made with Mine B concentrate are less porous, and pellets made of Mine A and Mine D concentrates have similar structures. In pellets made with Mine C concentrate almost all the bondings between particles are ceramic bridges of Si and Ca (even though bentonite was not added). These are also the pellets that presented highest compressive strength (398.0 kgf/pel); the lowest was Mine D concentrate pellets (145.2 kgf/pel).

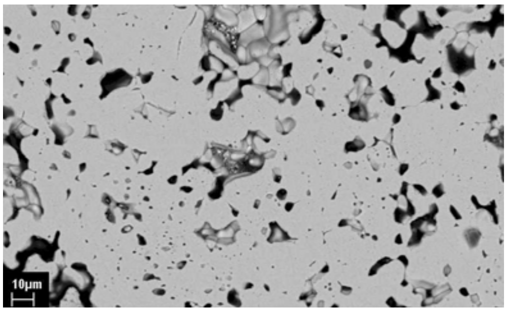
Figure 3 presents the photomicrographies of pellets obtained using bentonite as a binder. Mine A and Mine B concentrate pellets had lower compressive strengths when compared to their pure concentrate pellets. In these cases, ceramic bridges are thought to be a point of weakness.

The photomicrographies of pellets made using organic binder are shown in Figure 4. In this case, pellets made with Mine B concentrate shows less and smaller pores, and Mine A and Mine D pellets have similar structure; the same behavior was achieved when analyzing the pure concentrate pellets. The use of *organic* binder improves the compressive strength for all four iron ore concentrates studied. Even though the action of this binder is not creating ceramic bridges, it was found a remarkable number of these bridges in the Mine C concentrate pellets, what also occurred when analyzing the pure concentrate and bentonite bindered Mine C pellets.

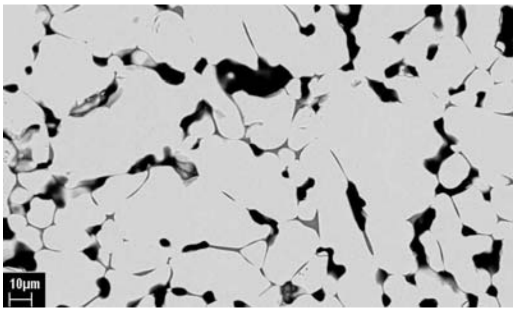
Mine A (100%) **192,6 kgf/pel**



Mine B (100%) **191,8 kgf/pel**



Mine C (100%) **398,0 kgf/pel**



Mine D (100%) **145,2 kgf/pel**

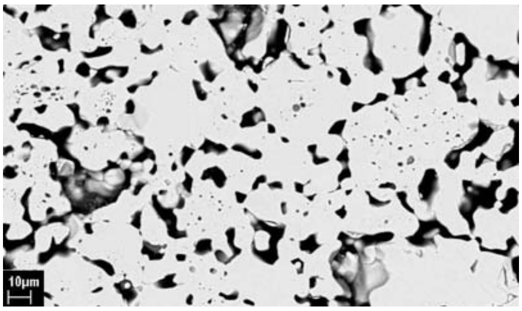
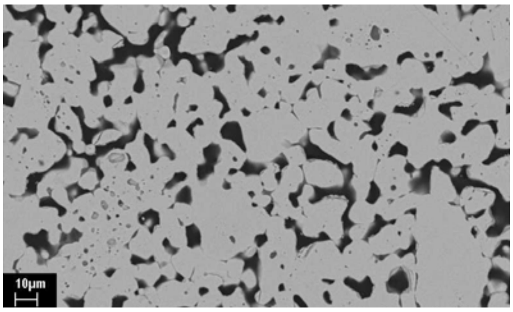
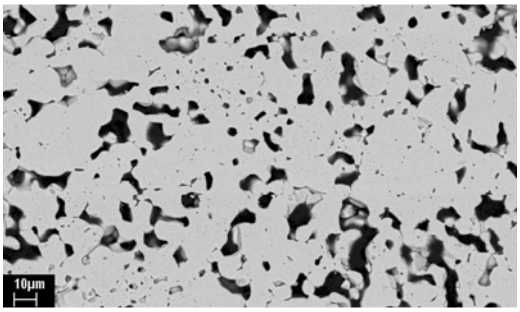


Figure 2 – Pure Concentrates – Photomicrographies of fired pellets

Mine A + bentonite **142,8 kgf/pel**



Mine B + bentonite **119,9 kgf/pel**



Mine C + bentonite **435,5 kgf/pel**

Mine D + bentonite **185,4 kgf/pel**

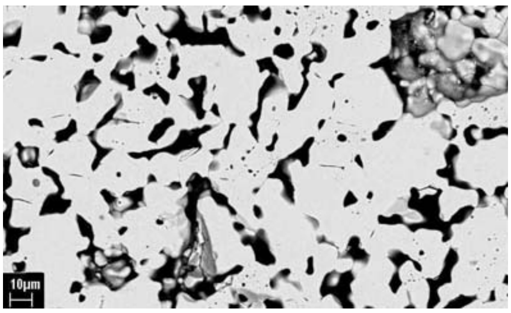


Figure 3 – Concentrates + bentonite – Photomicrographies of fired pellets

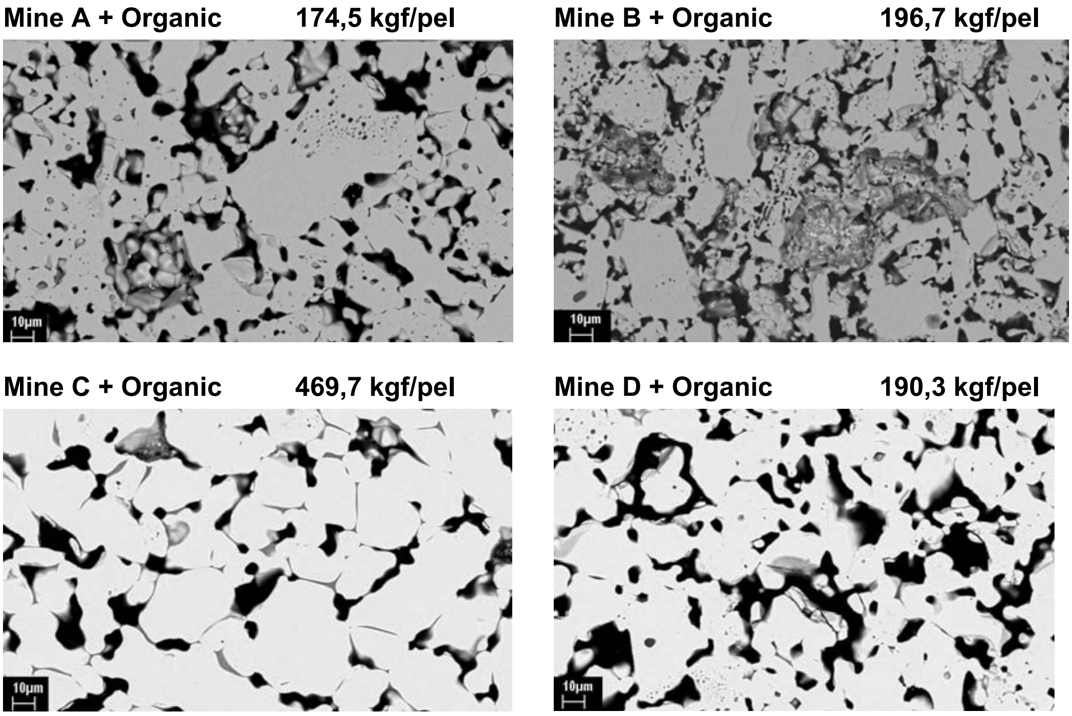


Figure 4 – Concentrates + Organic – Photomicrographies of fired pellets

4 CONCLUSIONS

This paper aimed to identify which binder – organic or inorganic- is the most effective in maximizing compressive strength of thermally treated pellets produced with four different Brazilian iron ore concentrates, named Mine A, Mine B, Mine C and Mine D. Binders and iron ore concentrates were provided by mining companies.

Although compressive strength is not the only requirement to be attended by the final product, it was selected as subject of this project since it has been made research efforts to improve this parameter, in order to obtain pellets able to remain intact during handling and to transoceanic transportation.

Results presented in this paper show that the organic binder, when compared to bentonite, has the best performance when obtaining the final product for all iron ore concentrates studied. Also, the use of such like binders allows to obtain higher iron grade pellets, as desired by industry.

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