ISSN 2176-3135
ICSTI
6th International Congress on the Science and Technology of Ironmaking - ICSTI
42th Ironmaking and Raw Materials Seminar/ 42º Seminário de Redução de Minério de Ferro e Matérias-primas
13th Brazilian Symposium on Iron Ore/ 13º Seminário Brasileiro de Minério de Ferro

CORRELATION BETWEEN THE COLD COMPRESSION TEST AND ABRASION RESISTANCE TEST (ASTM E 279-97) IN SELF-REDUCING PELLETS[1]

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Abstract
Mechanical properties are very important on development of self-reducing technologies of iron ore raw materials. In order to use the self-reducing pellets, is necessary to improve their mechanical stresses and abrasion resistance. In the iron ore reduction processes, the self-reducing pellets need to present a good cold crushing strength to support the material column weight within the blast furnace, or need a wear resistance when they are being transported or handled in a rotary kiln; In this work, the cold compressive strength and resistance to abrasion were measured in terms of the graphite concentration. The abrasion resistance was measured by tumbler test (ASTM 279-97). It was prepared different self-reducing pellet of 17 mm diameter, containing iron ore, graphite and with 10% mass of Portland cement High Initial Strength (HIS). The cement was kept constant at level of 10% and iron ore plus graphite proportions was changed from 90/0 up to 0/90 respectively. This selected method enables a more uniform variation of the mechanical strength of the pellets, keeping constant the amount of cement. It was obtained compressive strengths of mixtures, testing 10 samples for each composition of pellets. Samples were tested in the tumbler, adjusting the drum volume to sample quantity and was measured the amount of retained material in the 6.3 mm mesh sieve. The results with increasing graphite content presented a decrease on compressive strength and increase on abrasion resistance.
Keywords: Self-reducing pellets; Tumbler test, Compression test; Abrasion; Friction.

[1] *Technical contribution to the 6th International Congress on the Sicence and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*
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ISSN 2176-3135

1 INTRODUCTION

The cold and hot mechanical behavior of self-reducing pellet is of great interest for development of reduction technology. The resistance to heavy loads, as occurs in blast furnaces can be studied with compression tests and the resistance to movement that can occur during transportation or processing in the rotary kiln can be studied by tumbler tests. Understanding these tests and their relationship are of vital importance.

1.1 Pellet Strength Considerations

Iron ore green pellets were balled with the viscous bentonite binder showing no difference in wet compression strength compliance with raw material fineness and the particle size distribution within realistic process variations. The main binding force is the viscous force, which only less than one half of the green pellet strength was originated from the capillary forces and it is sensitive to changes in raw material fineness [1].
Increasing fineness and a broader particle size distribution in raw material result in increasing green strength of the agglomerates, which does not apply in large-scale balling of iron ore green pellets, as long as the specific surface area of the raw material is within the ballable area. This information is of great importance for the control of the balling circuits: variations in the grind of the pellet feed would not show in the green pellet wet compression strength, whereas the green pellet plasticity is kept constant by adjusting the moisture content [1].
Other green pellet properties such as abrasion strength, growth rate, oxidation rate of magnetite iron ore and sintering rate are expected to change with raw material fineness. Fineness has a major impact on the moisture content which is needed to create plasticity in green-pellets [1].
Regarding the generation of pellet strength during drying process, there are two different mechanisms to work at the early stage and the last stage before complete dryness. The rise in strength at the early stage of drying is considered attributable to the increase in liquid viscosity due to the condensation of micro-particles and APD (anionic polymer dispersant) in the liquid and the increase in strength just before complete dryness is considered attributable to the formation of solid bridges caused by the movement and rearrangement of micro-particles [2].

1.2 Abrasive Considerations

Abrasive wear can be divided into two main categories. The first one, called single wear, where particles are rigidly fixed in a body, and wear of three abrasive bodies (figure 1), in which abrasive particles are free to rolling between the bodies, therefore, remaining part of the time scratching the surface [3].

ISSN 2176-3135

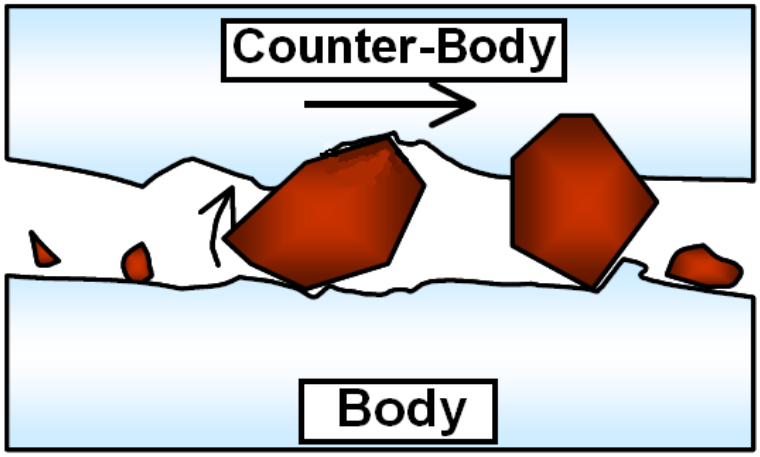

Figure 1. The schematic representation of wear three abrasive bodies [3].

During the wear, kinetic energy is transformed into particle deformation. Three typical failure modes are distinguished: (a) the peeling mechanism, (b) the erosion mechanism and the (c) layer fatigue mechanism, all of them can occur at the same time. The peeling mechanism is produced by a high attrition, followed by an erosion mechanism. The layer fatigue mechanism is more prevalent. The measure of the tangential force resistance of the particles gives the result of abrasion level.
The abrasion coefficient is unique for each substrate. The major difference between abrasion and attrition testing is the absence of the accelerated removal of sharp edges in abrasion testing when compared with attrition testing. Attrition occurs when a particle impacts perpendicular against a target and abrasion occurs when a particle slides against a target. The morphology and the roughness of the surface of the particle affect the abrasion and attrition mechanism [4].
The shear stress of particles in a dry powder blend is very low. This implies that fracture is not the dominating mechanism of size reduction of aggregates. Abrasion is the size reduction predominating mechanism of aggregates. There is a correlation between porosity and abrasion rate [5].
The kinetic energy density of the moving powder bed (Wb) is a relevant parameter to explain abrasion rates of agglomerates. The Stokes Abrasion number (StAbr) has been defined as the ratio between the kinetic energy density of the moving powder bed and the work of fracture of the agglomerate. This StAbr number is used to explain the abrasion rate of agglomerates during dry-mixing. Applying StAbr revealed that abrasion of agglomerates is not only depending on rotational speed or filler particle size alone, but it can be determined by all parameters that describe the StAbr number of the system [6].

2 MATERIALS AND METHODS

2.1 Characterization of Raw Materials and Self-Reducing Pellet Studied

For different tests were produced using as raw material iron ore (pellet feed), graphite and Portland cement type HIS (high initial strength). The chemical compositions and particle sizes raw material are given below (Table 1 to 3).

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Table 1. Chemical composition of iron ore (Pellet feed) (% mass)

Fe_2O_3	Gangue	Al_2O_3	SiO_2	MnO_2	P	Ignition loss
97.9	2.1	0.6	1.4	0.1	0.03	0.7

Table 2. Particle size analysis of iron ore (pellet feed) (% mass)

+ 1 mm	1 – 0.15 mm	0.15 – 0.045 mm	- 0.045 mm
2.0	12.0	56.0	30.0

Table 3. Chemical composition of Portland Cement of high initial strength (HIS).

Component	% mass	Component	% mass
CaO	64.3	K_2O	0.7
SiO_2	19.1	MgO	0.6
Al_2O_3	4.9	Na_2O	0.1
Fe_2O_3	2.8	Lime free	1.0
SO_2	2.6	Others	4.0
Supplier´s analysis			

2.2 Self-reducing Pellet Elaboration

The iron ore and graphite were previously divided, and dried at 120 °C for two hours. Then 400 g of mixtures were prepared as indicated in Table 4. These pellets were prepared varying the graphite concentration for obtaining gradual different values of compressive strength for same concentration of binder.

Table 4. Compositions of self-reducing pellets.

Iron Ore (%mass)	Graphite (% mass)	HIS Cement (% mass)
100.0	0	+10.0
90.0	10.0	+10.0
80.0	20.0	+10.0
70.0	30.0	+10.0
50.0	50.0	+10.0
20.0	80.0	+10.0
0	100.0	+10.0
Cement HIS was added later at mixture of iron ore and graphite.		

In order to homogenize the mixture, a Turbula mixer was used as shown in Figure 2. Then, it was added plus 10% in mass of water in each mixture, and the pellets were handmade controlling the mean diameter to 17 mm. The pellets were cured for a 15 days period. Thereafter, the pellets were weighed and measured, to obtain the bulk density depending on the graphite concentration (Figure 3).

2.3 Cold compression test of self-reducing pellet.

Once obtained the pellets of different compositions, and respecting the curing time, the pellets were dried at 120 °C for 2 hours. From each sample were tested 10 pellets in the EMIC press of Figure 3, obtaining the average of the values of cold compression resistance of each. With these values, and the composition was prepared a graph of the cold compressive strength versus graphite concentration figure 6.

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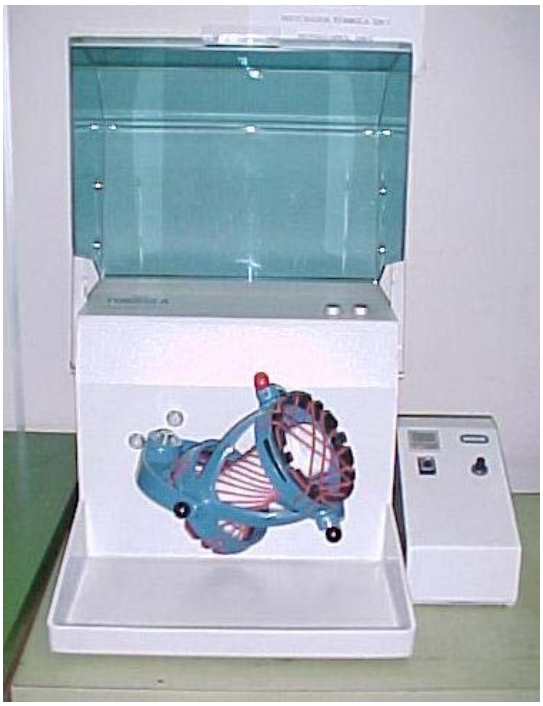

Figure 2. Turbula mixer to homogenize the mixture.

Figure 3. EMIC Press for compression tests, with capacity up to 30 tons.

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2.4 Abrasion Test of Self-reducing Pellet, ASTM 279-97

In order to study the effect of the graphite concentration on the abrasion resistance of the self-reducing pellets the tumbler test, ASTM 279-97, was applied at each of the compositions. The results are shown in the Table 4.

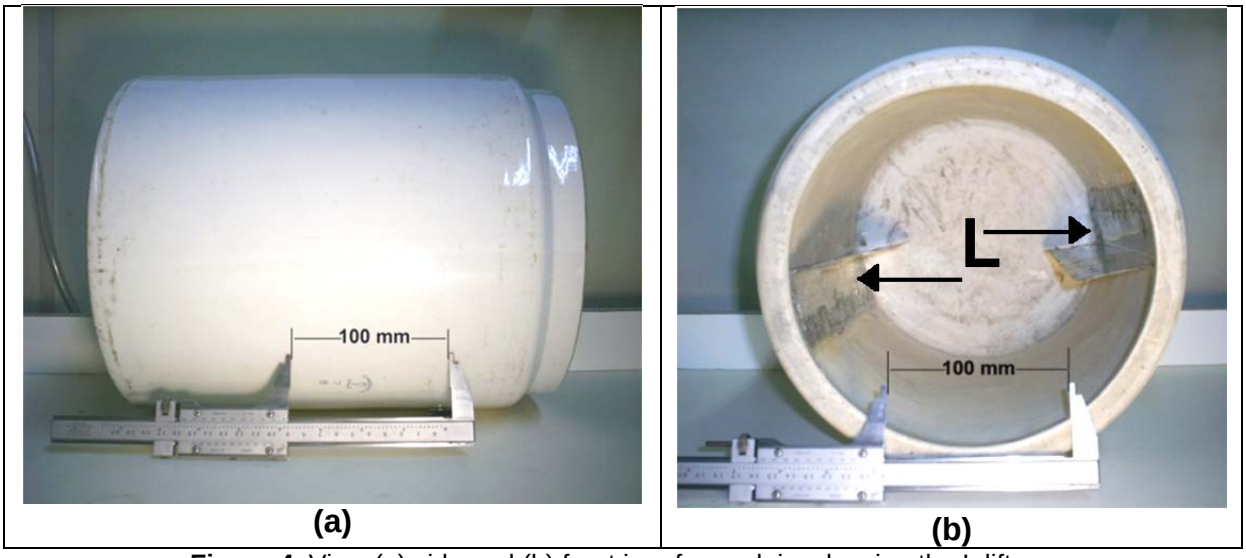

Figure 4. View (a) side and (b) front jar of porcelain, showing the L lifters.

ASTM 279-97 norm request a mass of 11.0 kg by test, which overcomes the amount of material available, for these reasons was resize the sample volume. It was used an amount of 300 ± 0.1 g in a porcelain jar that measured 300 ± 1 mm internal length (Figure 4a) and 200 ± 1 mm in inner diameter (Figure 4 b) approximately, with two L lifters of 50.8X50.8x1.0 mm. The previously dried material was processed at 200 revolutions with a rotation of 24 ± 1 RPM, in an assembly as shown in Figure 5. The material was separated by sieve in a 6.3 mm mesh size to obtain the percentage of retained and passing material. With these data, it was plotted the quantity of material accumulated in term of graphite concentration, and was compared with compression resistance plot (Figures 6 and 7).

ISSN 2176-3135

Figure 5. Assembly for tumbler test.

3 RESULTS AND DISCUSSION

The compressive strength versus graphite concentration is shown in Figure 6. It evidenced that with increasing graphite concentration the compression strength decreases. It would be happened for many reasons: graphite possibly facilitates the movement of broken plans; or graphite has a lower mechanical strength than the iron ore and therefore facilitating the fragilization of the self-reducing pellet. Another reason would be the increase of volume of material with increase of graphite content, for a constant quantity of binder. That is, the pellets bulk density decreases with the increase of graphite concentration as is shown in Figure 9.

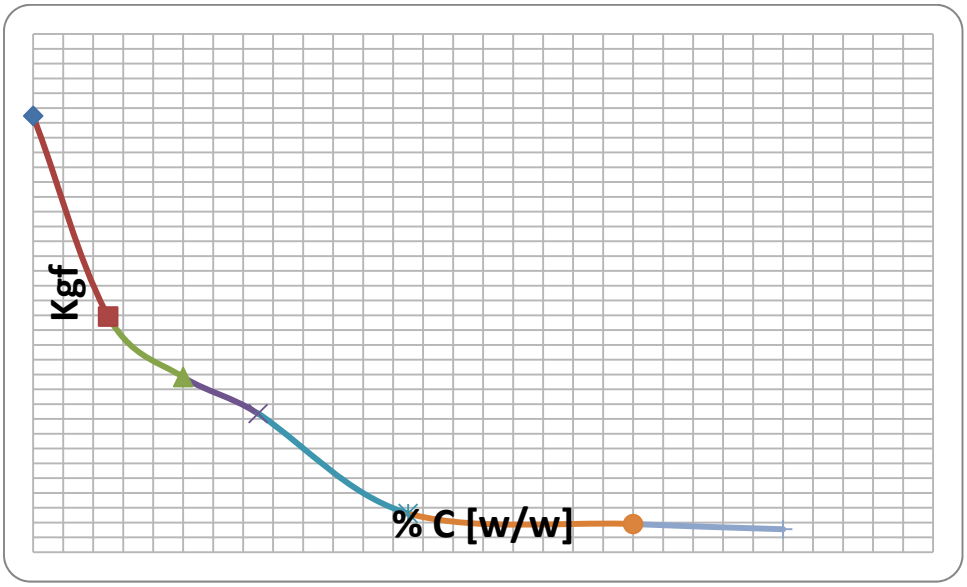

Figure 6. Compressive strength as a function of the graphite concentration.

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After the tumbler abrasion test particle size greater than 6.3 mm was determined for increasing concentration of graphite, as it is shown in Figure 7. The higher percentages of mass retained were obtained with the higher graphite concentrations. The tumbler abrasion test involves a complex process, where different mechanisms exist but the impact and the abrasion are more important ones.

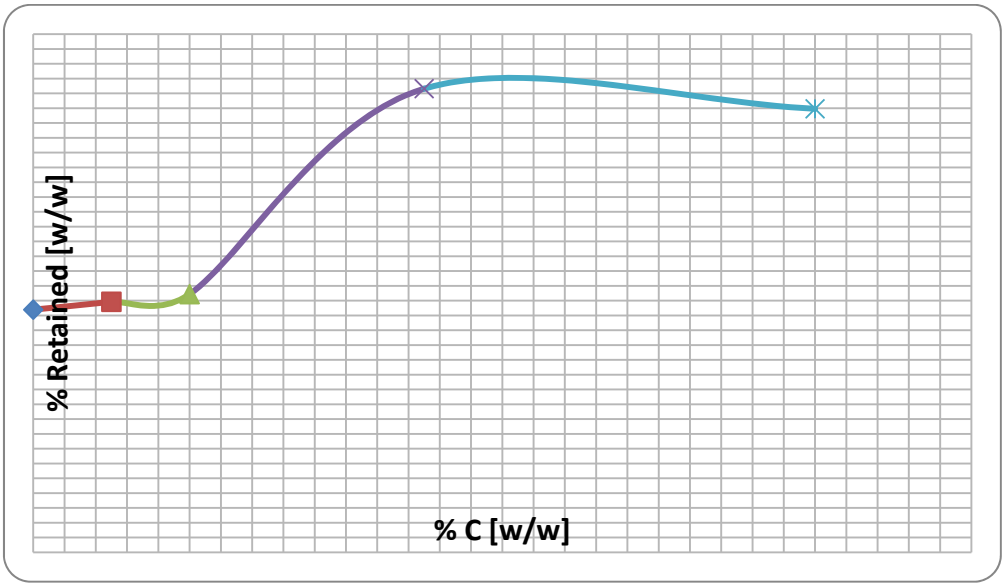

Figure 7. Mass percent retained of tumbler test depending on the graphite concentration.

The pellets with better responses to impact and abrasion have a better performance. In this study, the increases of graphite percentage improve plastic behavior which enhances impact resistance of pellets. Graphite has low friction coefficient compared with other materials, which also helps to reduce the material abrasion. It can be also performed an inverse analysis. Increasing iron ore concentration in the pellets, the abrasion is accelerated.

The variation of the cold compressive strength and abrasion resistance as a function of graphite concentration is shown in Figure 8 which evidences a low abrasion resistance increasing the compressive strength. Pellets with high compressive strength may have poor abrasion performance and vice versa, that means, pellets with low compression resistance can provide a good abrasion resistance.

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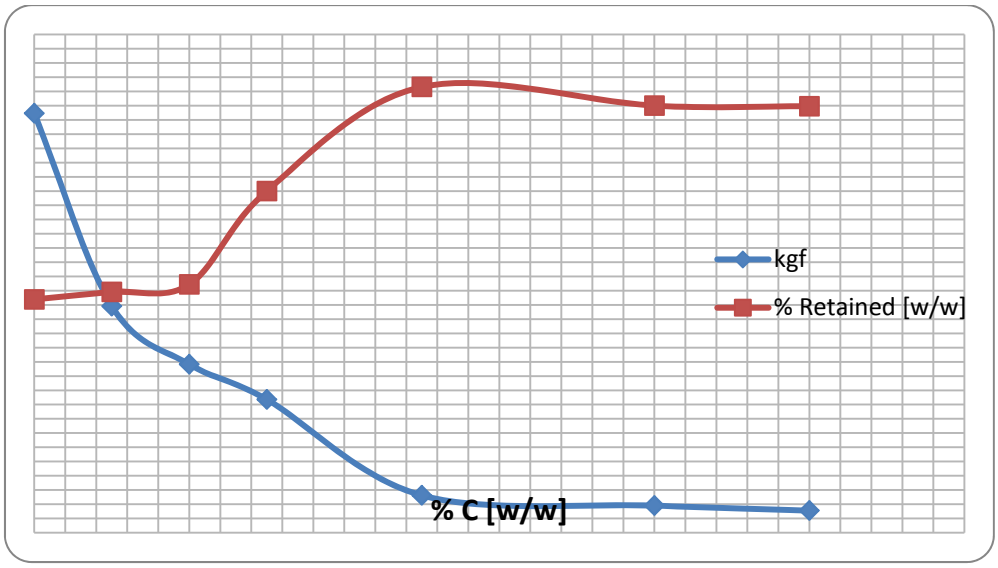

Figure 8. Cold compressive strength and abrasion resistance as a function of graphite concentration.

As seen in Figure 9, high graphite concentrations decrease the bulk density, which reduce the impact effect, because the loads become lighter.

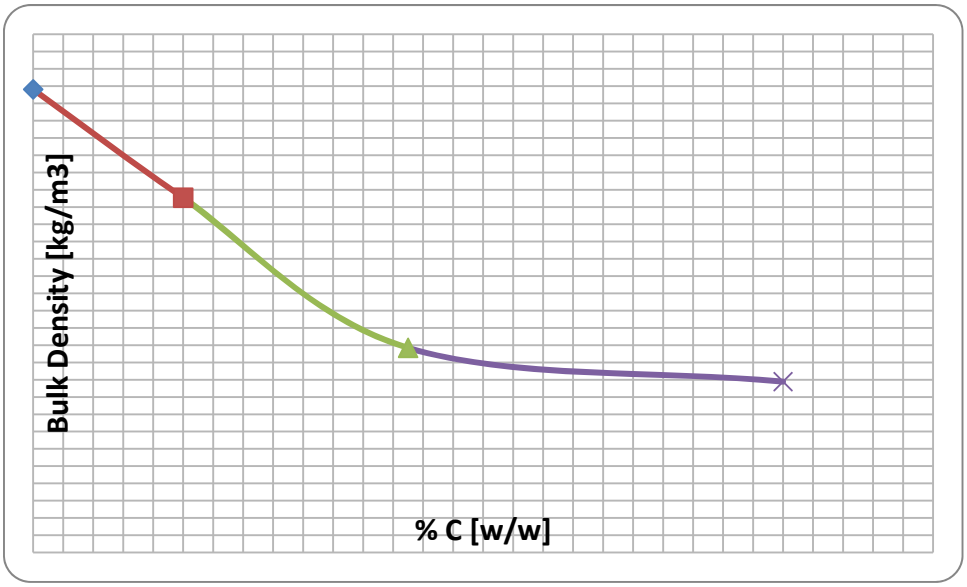

Figure 9. Bulk density of the self-reducing pellets as a function of the graphite concentration.

4 CONCLUSIONS

- Evaluating self-reducing pellets using ASTM E 279-97 standard and compression strength test showed the following characteristics:
- An increase of graphite concentration decreases the cold compression strength.
- As graphite concentration increases the impact and abrasion resistance increase.
- An increase of cold compression strength does not imply an increment of impact and abrasion resistance, and vice versa.

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- The increase of graphite concentration decreases the bulk density which decreases compression strength and increases the impact resistance of the pellets.

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