http://dx.doi.org/10.1590/0370-44672015690198

Comminution circuits for compact itabirites

Pedro Ferreira Pinto
Engenheiro de Desenvolvimento de Processo, Vale
Diretoria de Programação Integrada
Nova Lima – Minas Gerais - Brasil
pedro.ferreira.pinto@vale.com

Homero Delboni Júnior
Professor
Universidade de São Paulo - USP
Escola Politécnica
Departamento de Engenharia de Minas e de Petróleo
São Paulo – São Paulo - Brasil
hdelboni@usp.br

Abstract

In the beneficiation of compact Itabirites, crushing and grinding account for major operational and capital costs. As such, the study and development of comminution circuits have a fundamental importance for feasibility and optimization of compact Itabirite beneficiation.

This work makes a comparison between comminution circuits for compact Itabirites from the Iron Quadrangle. The circuits developed are: a crushing and ball mill circuit (CB), a SAG mill and ball mill circuit (SAB) and a single stage SAG mill circuit (SSSAG). For the SAB circuit, the use of pebble crushing is analyzed (SABC). An industrial circuit for 25 million tons of run of mine was developed for each route from tests on a pilot scale (grinding) and industrial scale. The energy consumption obtained for grinding in the pilot tests was compared with that reported by Donda and Bond.

The SSSAG route had the lowest energy consumption, 11.8kWh/t and the SAB route had the highest energy consumption, 15.8kWh/t. The CB and SABC routes had a similar energy consumption of 14.4 kWh/t and 14.5 kWh/t respectively.

Keywords: compact Itabirites; SAG mill; grinding circuit; iron ore.

1. Introduction

Iron ore grade reduction in Brazilian deposits, mainly in the Iron Quadrangle, results in the need for concentration in order to meet the specifications of the steel industry. This context applies for a large number of mines that nowadays operate with Hematite or high grade Itabirite and who in the near future, will have to beneficiate low grade and compact Itabirite.

The beneficiation route for compact Itabirite included the comminution of all plant feed followed by a desliming and a reverse flotation for production of Pellet Feed. In this kind of circuit, crushing and grinding account for the major operational and capital costs in reason of energy consumption and the large scale of the equipment and buildings. In this context, the study and development of comminution circuits is an important way to make the beneficiation of compact Itabirite feasible. Pereira *et al* (2010), Vasconcelos *et al* (2010) and Uliana *et al* (2012) study the comminution of compacts Itabirites for different mines in the Iron Quadrangle. This work will make a comparison between comminution circuits for compact Itabirites from the Iron Quadrangle. The circuits developed are: a crushing and ball mill circuit (CB), a SAG mill and ball mill circuit (SAB), and a single stage SAG mill circuit (SSSAG). For the SAB circuit, the use of pebble crushing is analyzed, SAB/C route. Figure 1 shows the grinding circuits studied in this work.

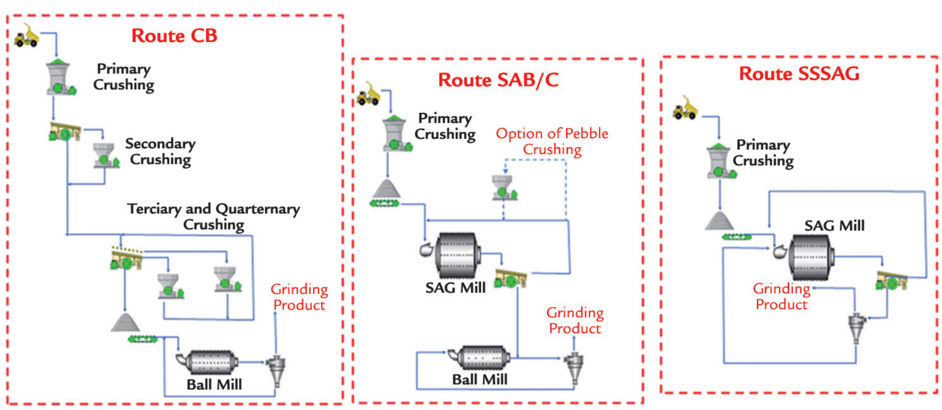

Figure 1
Grinding Circuits.

For each circuit, the energy consumption and design of comminution equipment for a circuit processing of 25 million tons per year (Mty) is analyzed. The ground product must have 10% of its particles above 0.15mm.

Lima *et al* (2013) show a potential reduction of 15% in the capital costs (CAPEX) and 7% in the operational costs (OPEX) with the use of SAB route, for Itabirites with an Operating Work Index higher than 7,8kWh/t.

2. Methodology

The study was made with a sample of 2000 tons of a compact Itabirite collected in a Vale mine in the Iron Quadrangle. This sample was not meant to represent any specific mine, but a typical compact Itabirite, with more than 80% above 1 mm and Bond WI exceeding 10 kWh/t. In this way, the results obtained can be used as references for mines that have a large participation of compact Itabirites. Complete information about the tests and sample characterization can be found in Pinto, 2016.

The characterization of sample comprises the following tests:

1 – Bench scale test:

1.1- Bond Work Index: Determination of Ball Mill Work Index using Bond methodology (BOND 1964). The test considered a 0.106mm screen to close the circuit. The results were used to fit the JKSimet™ software and to predict energy consumption in the grinding circuit using the Bond methodology (BOND 1964). The energy consumption predicted was compared with the energy consumption obtained by pilot tests.

1.2 Drop Weight Test and Abrasion Resistance: Determination of the impact breakage and abrasion breakage parameters (NAPIER-MUNN et al 1999). The results were used to fit the JKSimet™ software.

1.3 Donda Test. Determination of Donda energy consumption parameter, K (DONDA 2003). The results were used to predict the energy consumption in a grinding circuit using the Donda methodology (DONDA, ROSA 2014). The energy consumption predicted was compared with energy consumption obtained by pilot tests

2 – Industrial crushing test to obtain the crushing efficiency for compact Itabirite, in function of the closed side setting (CSS). The test was made in a Metso HP300™ cone crusher with a 25 mm CSS. From the results of this test, the efficiency of crushing for different CSS's was simulated in the JKSimet™ software.

3 - Pilot tests using ball mill and SAG mill circuits to obtain the energy consumption. For CB and SSSAG routes, a simulation was made with the JKSimet™ software to adequate the grinding product to 10% above 0.15 mm, as aimed in the industrial circuit. The dimensions of the mills and the operational parameters of the pilot tests are shown in Table 1.

Test/Route	Mill Diameter (m)	Mill Length (m)	% Balls	Ball Top Size (mm)	% Critical Velocity
Ball Mill/CB	1.57	0.95	33	101.6	64.5
SAG Mill/SAB	1.74	0.48	4	101.6	75.0
Ball Mill/SAB	0.91	1.22	35	76.5	69.0
SAG Mill/SSSAG	1.74	0.48	4	101.6	75.0

Table 1
Pilot Grinding Tests Parameters.

The design of the industrial circuit does not comprise the primary crusher because this operation was the same for all circuits. For the crushing circuit, 6000 operational hours per year were considered, and for the grinding circuit, 7800 operational hour per year was considered. As the circuit was designed for 25 Mt/y, the mass flow was 4167 tons per hour (t/h) in the crushing circuit and 3205 t/h in the grinding circuit.

3. Results

The results of the bench scale tests, are shown in Table 2.

DWT and Abrasion			Grinding Test	
Parameter	Value	Classification	Parameter	Value
A	38.8	Medium Impact Resistance	WI Bond (kWh/t)	10.9
b	1.398			
Axb	54.24		K Donda (t/kWh)	0.161
ta	0.550	High Abrasion Resistance		

Table 2
Bench Scale Test.

Pereira *et al* (2010), in a characterization for Compacts Itabirites of Serra Azul, obtained an impact resistance (Axb) between 33 and 157 and a Bond WI between 8.7 kWh/t and 12.0 kWh/t.

Particle size distribution for the feed of industrial crushing test and pilot grinding tests are shown in Figure 2. The SAG mill pilot test and crushing test, used the same sample, without crushing. For ball mill pilot test, the sample was crushed until 12.5mm.

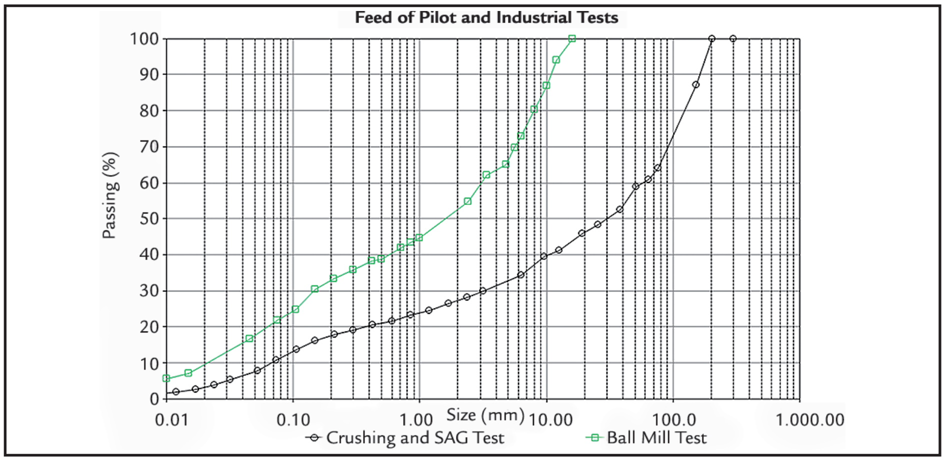

Figure 2
Feed of Pilot and Industrial Tests.

Figure 3 shows the crushing efficiency in function of size, for different CSS obtained in the industrial test and by simulation.

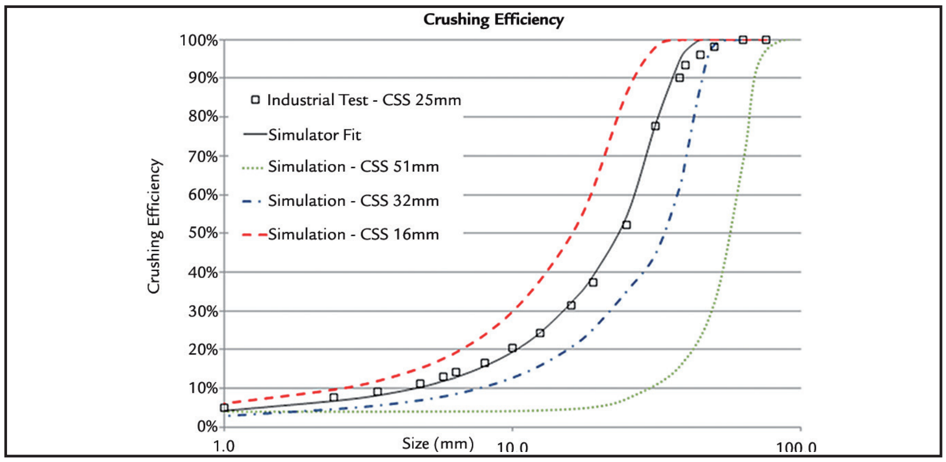

Figure 3
Crushing Efficiency.

The mass balance of the crushing circuit for CB route, with the size reference and equipment design is shown in Table 3. The crushers reference of unit capacity was obtained in the manufacture's manual (SANDIVIK 2011).

Flow	Mass Flow		Size (mm)			
	th	%	+76,2	+38,1	+25,4	+1277
Product Primary Crushing	4167	100.0	64.0	52.6	48.3	41.3
Feed Secondary Crushing	1731	41.5	14.8	5.6	4.8	4.0
Product Secondary Crushing	1731	41.5	97.7	47.5	31.5	18.0
Undersize Peneira Secondary	2436	58.5	99.0	86.0	79.2	67.8
Feed of Terciary/Quaternary Screen	11466	275.2	99.4	84.2	74.5	41.4
Feed Terciary Crushing	1980	47.5	96.7	26.2	17.3	9.6
Product Terciary Crushing	1980	47.5	100.0	71.8	46.4	24.0
Feed Quartenary Crushing	5319	127.7	100.0	93.5	75.8	8.8
Product Quartenary Crushing	5319	127.7	100.0	100.0	96.7	43.4
Crushing Circuit Product	4167	100.0	100.0	100.0	100.0	98.2

Crushing Step	Equipment Power (kWh)	CSS (mm)	Unit Capacity	Equipments Calculated	Equipments Adopted
Secondary	600	51	1704	1.0	2.0
Terciary	600	32	1277	1.6	2.0
Quaternary	600	16	732	7.3	8.0

Table 3
Crushing Circuit – Mass Balance and Design.

The energy consumption of crushing plants (secondary to quaternary) was 2.0 kWh/t.

Table 4 compares the energy consumption and the mill design obtained from the pilot tests using Donda and Bond methodologies for the routes studied. The product of the grinding has 10% of particles above 0.15mm for all circuits. Mill diameter and length were obtained using the total power requirement and Austin equation for SAG Mill (AUSTIN 1990) and Rowland equation for Ball Mill (ROWLAND 1986).

Route	Energy Consumption (kWh/t)			SAG Mill Desing			Ball Mill Desing		
	Pilot Test	Bond	Donda	Diameter and Length (feet)	Number of Equipments	Total Power (MW)	Diameter and Length (feet)	Number of Equipments	Total Power (MW)
CB (Ball Mill)	12.4	8.8	12.0	-	-	-	26 x 40	3	39.6
SAB	15.7	10.8	14.7	40 x 34	1	26.1	26 x 38	2	25.2
SABC*	14.3	10.6	14.0	38 x 32	1	21.6	26 x 38	2	25.2
SSSAG	11.9	10.2	13.2	36 x 33	2	38.8	-	-	-

* For this route, two pebble crusher of 600kW must be considered, with an additional energy consumption of 0.2kWh/t.

Table 4
Grinding Circuits – Energy Consumption and Design.

The amount of slimes, material below 0.010 mm, in the product of the grinding is an important parameter for the grinding circuit. Slimes are prejudicial for the beneficiation circuit and must be removed from the circuit before flotation, so that, a large amount of slimes reduce the global mass recovery of the plant.

Table 5 compares the amount of slimes obtained in the grinding product of pilot test for each circuit analyzed.

Slimes (<0.010 mm) in Grinding Product	Pilot Test
CB (Ball Mill)	13.7
SAB	14.4
SABC	13.6
SSSAG	14.7

Table 5
Grinding Product Slimes.

4. Conclusions

The SSSAG route had the lowest energy consumption, 11.8 kWh/t and the SAB route had the highest energy consumption, 15.8 kWh/t. The CB and SABC routes had a similar energy consumption of 14.4 kWh/t and 14.5 kWh/t respectively.

The energy consumption in the SSSAG route was lower than the ball mill consumption, 12.4 kWh/t, even with a new feed size without previous crushing in the SSSAG.

The energy consumption provided by the Donda methodology was close to that obtained in tests on a pilot scale for the CB and SAB/C routes. In contrast, the energy consumption provided by the Bond methodology was lower than the results obtained on a pilot scale for all routes studied.

Use of pebble crushing led to a reduction of 18.8% in the SAG mill power consumption for the SAB/C route, without increase in power consumption in the ball mill.

The amount of slimes in the grinding product was very close in all routes, ranging from 13.6% in the SAB/C route to 14,7% in the SSSAG route. With these results, it is not possible to clearly see a tendency of major slimes generation for any routes.

5. Acknowledgements

We wish to thank Vale, especially the team from the Research Development Center (CPT) for all the support for this work.

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Received: 16 December 2015 - Accepted: 06 June 2016.