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EVALUATION OF A GRINDING AND REGRINDING PROJECT OF AN ITABIRITE ORE

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ABSTRACT

Two samples of iron ore were tested for evaluation of kinetics parameters. The first sample corresponding to HPGR product obtained in pilot tests conducted by KHD and the other being one final coarse concentrate. The tests were carried out in a ball mill on a laboratory scale with a torque device for accurate measurement of power. The kinetic parameters of the samples were obtained by Moly-Cop Tools 2.0. Simulations were performed with the same application for forecasting the behavior of the grinding circuit with each of the samples studied. The results demonstrate that the grinding circuit previously evaluated will achieve the request and there will be possibilities to optimization in the regrinding circuit especially in terms of energy consumption.

KEYWORDS: Grinding, Simulation, Optimization, Itabirite Iron Ore

1. INTRODUCTION

Determining energy consumption and the mill scale-up has been target of the scientists since the XIX century, starting with Rittinger and Kick. Recently, techniques involving mathematical modeling have been successfully applied to both processes.

The increasing demand, in contrast to a decrease of quality of useful mineral content of Brazilian iron ore, has caused that the cost associated with grinding stage, both in implementation and in operation, gain an importance every day higher.

In the past, most of the mill scale-up work was based, directly or indirectly, on the empirical Bond energy size reduction equation. This approach was used extensively in the minerals industry and in accordance to some researchers (Austin et al., 1984) Bond work index may be useful for mill design, but not for optimization of operating ball mills. The main limitations of Bond´s equation are associated to the fact that it does not allow decoupling the contributions of the mechanical environment, the mill transport and size classification. As such, the empirical equation for specific energy calculation implicitly assumes that the breakage kinetics, transport through the mill and classification sub processes, are characterized by a single parameter, the work index (Wi), (Faria, 2015).

Several studies have been carried out in the development of detailed phenomenological grinding models derived from population balance considerations (.In these models the explicit accounting of grinding sub processes (size reduction kinetics, material transport in the mill and size classification) gives them significant advantage over the simpler energy size reduction equations. This type of model, in its complete form, is capable of describing the size distribution in a tumbling mill grinding as a function of time in batch grinding or steady state mill discharge in continuous mills (Herbst et al., 1968).

In order to evaluate the kinetic behavior of an itabiritic iron ore in the grinding process, simulation studies were performed with the results of laboratory tests. This study allowed us to evaluate the circuit in terms of particle size distribution, feed rate and energy consumption (kWh / ton) in an industrial reference design. The reference project provides will processing 54.7 Mtpy dry basis of iron ore through primary crushing, screening, secondary crushing, roller press - HPGR, followed by secondary crushing, cyclones classification, mechanical flotation of fraction -0.15 + 0.044 mm and columns flotation of fraction -0.044, and a regrind process to adjust the particle size distribution for pipeline. The project provides the production of 25 Mtpy of pellet feed for direct reduction.

2. EXPERIMENTAL WORK

About 100 kg of sample were sent to the laboratory of Chile University. The sample corresponds to the product of roller press (HPGR) obtained in pilot tests conducted by KHD. The other sample was the final coarse concentrate.

The sample was homogenized and splitted for performing the grinding tests.
For the determination of kinetic parameters, the grinding was divided into 0, 4 and 6 minutes with monitoring of energy consumption (torque). The digital data acquisition, such as power consumption, amperage, voltage, and other parameters, is performed by a software installed on a computer.

The tests were carried out using a laboratory scale ball mill.
Table 1 shows the design and operating variables used in the tests. Samples were ground in different time intervals in wet basis and with two different ball charge distribution.

Were used the diameters of 2.0, 2.5 and 3.0 inches for the HPGR discharge material, and 1.0, 1.5 and 2.0 inch and 20 mm cylpebs for the regrinding test.

Table 1: Design and operating mill variables used in the tests

Mill Diameter (m)	0.456
Mill Length (m)	0.381
Ball Charge Level (%)	29.9
Critical Speed (%)	75.2

3. RESULTS AND DISCUSSION

GRINDING TESTS AND SIMULATION

Obtaining the kinetic parameters:
The grinding tests with the product of roller press were made for different specific areas, and the results are shown in Table 2.

The Moly-Cop Tools 2.0 uses different letters to name the parameters of the selection and breakage functions. The letters are commonly used to describe these parameters are shown in parentheses (Austin et al., 1984).

The results of the HPGR product tests indicate the heterogeneity of the samples from the center and edge as indicated in table 2. While the ore has low grindability in the center, the ore of the edge is more efficient in terms of size reduction. The main parameter of primary grinding is the "critical D" since it represents the size of the ore which has the largest grinding efficiency for a given application.

For the simulations was considered 80% of center sample and 20% of the edge, and 3.0 ball diameter results.

Table 2. Kinetic parameters of the functions selection and fracture the product of HPGR, the center and edge.

	Center			Edge		
Ball Diameter	2.0	2.5	3.0	2.0	2.5	3.0
Area	94.5	75.6	63	94.5	75.6	63
α_0 (a)	0.00054	0.00052	0.00041	0,00093	0.00081	0.00053
α_1 (α)	1.313	1.304	1.299	1.328	1.321	1.314
α_2 (Λ)	2.46	2.47	2.47	2.45	2.45	2.47
$D_{critical}$ (μ)	9813	10187	10632	2663	3745	5405
β_0 (Φ)	0.04322	0.04318	0.04309	0.04438	0.04401	0.04388
β_1 (γ)	0.479	0.488	0.489	0.491	0.498	0.502
β_2 (β)	3.985	3.922	3.914	3.994	4.004	4.005

SIMULATIONS

With the data obtained in the laboratory tests, we can do a simulator able to reflect the industrial reality and show important information about energy consumption, particle size and feed rate. It had been used a reference data and then some modifications were made to adjust and refine a more efficient circuit. Following the circuit data:

Table 3: Data reference for simulation

Diameter x Length mill (m)	7.77 x 12.80 (25.5 x 42 ft)
Ball Charge Level (%)	35
Power (MW)	15.2
Mill Speed (rpm)/Critical Speed (%)	11.38/75
Cyclones Number	24
Cyclone Diameter (inches)	32
Inlet and Vortex (inches)	6
Solids overflow, underflow and feed (%)	34, 78 and 74
Feed Rate (ton/h) per mill	2,218
Feed size - F80 (mm)	8
Grinding media diameter (inches)	3.0

Reference simulation

Figure 1 shows the results of the first simulation with the reference data. In the first simulation, project data is compared with the parameters obtained in the laboratory by the mass balance.

The mass balance indicated an extremely high circulating load (593%). The power requirement was 7.21 kWh / ton and the specific energy consumption, 7.88 kWh / ton.

The classification process indicates a by-pass of 44.1% in fines, and a pressure of 43.76 psi (very high). The overflow obtained a product 80% less than 0.0985 mm and the design specification is 80% less than 0.15 mm.

For circuit optimization the following alternatives were chosen: increase the number of cyclones and evaluate the potential gains in productivity or energy to the same circuit designed and change the grinding media diameter.

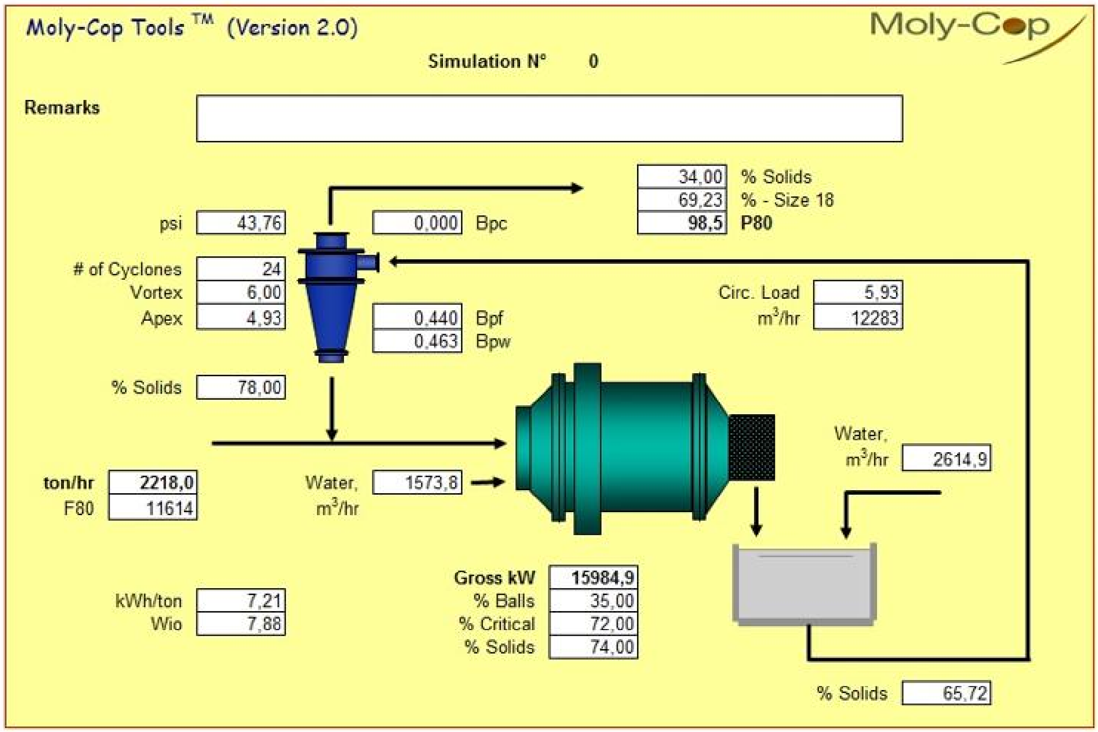

Figure 1: Mass balance – Reference Data

Simulation case 1 – optimization

The optimization considered the use of 34 cyclone of 32-inch with a 7.5-inch inlet and 8.0-inch vortex. The grinding balls diameter was maintained at 3.0 inches. The feed rate achieve 2,300 t / h for circuit stabilization.

The cyclone pressure remained within the range expected (9.6 psi) and the resulting circulating load was 282%. The product obtained reach P80=0.102mm. The particle size obtained by the circuit is quite thin.

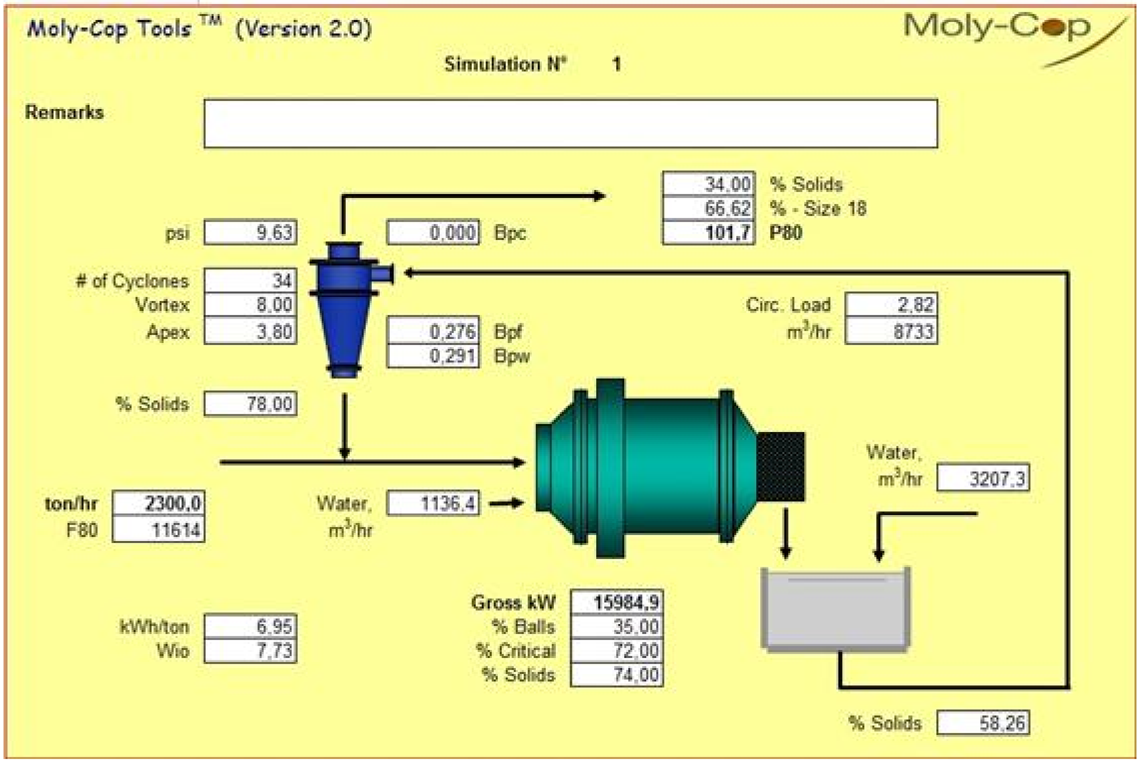

Figure 2: Simulation 1 – grinding

Regrinding test and simulations
Obtaining the kinetic parameters

The same way, the tests with recleaner concentrate of coarse flotation process were performed for different ball charge distribution (presented in table 4). The F80 were 0.106 mm and P80 0.048 mm.

Table 4. Kinetic parameters of the selection and breakage functions of final coarse concentrate.

Ball Diameter	1.0	1.5	2.0	Cone - 20 mm	Cone - 28 mm
Area	176.38	122.83	93.38	176.08	131.62
α0 (a)	0.00846	0.00573	0.00371	0.0124	0.00896
D critical (μ)	1991	2045	2762	1893	2033
β0 (Φ)	0.198	0.194	0.183	0.201	0.196

In the regrinding process the most important kinetic parameter considered for fine particle is α0. In this case, cones reach a better result and are considered for the simulations.

The reference data for simulation of regrinding circuit are presented in table 5.

Table 5: Data reference for simulation

Diameter x Length mill (m)	7.31 x 13.41 (24 x 44 ft)
Ball Charge Level (%)	35
Power (MW)	12.7
Mill Speed (rpm)/Critical Speed (%)	11.8/75
Cyclones Number	24
Cyclone Diameter (inches)	15
Inlet, Vortex, Apex (inches)	4.5, 6, 3
Solids overflow, underflow and feed (%)	31, 78 and 78
Feed Rate (ton/h) per mill	892.4
Feed size - F80 (μ m)	80
Product size – P80 (μ m)	44

Simulations

Reference Data

Figure 3 shows the simulation with the reference data for the regrinding circuit. The reference data are compared with the mass balance obtained with laboratory parameters.

With the simulation were identified some parameters that deserves more attention. They are:
P80= 16.8 μ m
Cyclone pressure = 15.2 psi
Specific energy = 14.4 kWh/t

The product size was bellow the specification (P80=44 μ m). This value means that there are the possibility to increase the feed rate or that the mill is oversized. The pressure obtained in cyclones indicates an value over the ideal (ideal pressure=13 psi) reaching 15.2 psi. In this case, besides the classification not be efficient, it will result in excessive wear of the cyclone parts. The energy consumption was 14.44 kWh/t. The alternatives simulation are to evaluate the circuit optimization.

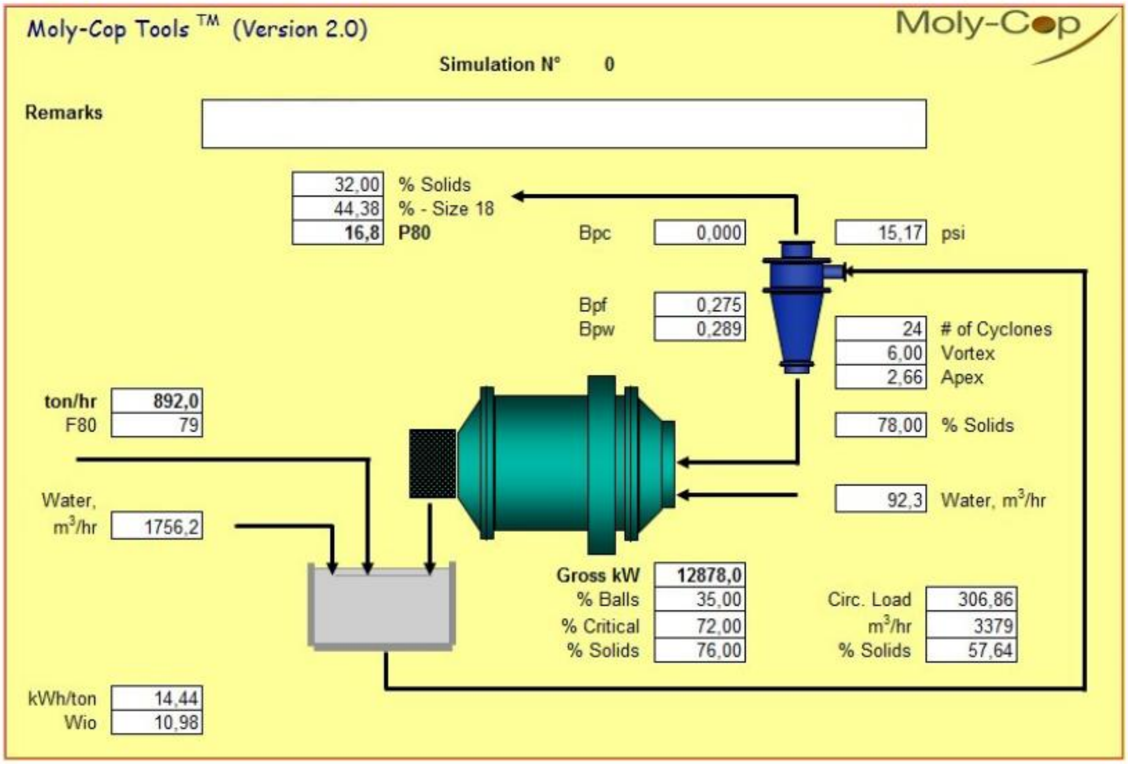

Figure 3: Mass balance – Reference data for regrinding process

Simulation – Optimization

One possibility of optimization could be increase the feed rate. But in this case it will not be interested to the company. The feed rate needs to be fixed because the production is still predeterminated.

The regrinding process presents a low reduction ratio. This way, a mill with big diameter and lenght contains a very large residence time. For the project conditions, the ideal will be operate com smaller mills.

The simulation present in figure 4 achieve a P80=0.045 mm with an energy consumption of only 4.61 kWh/t, circulating load of 267% and 28% fines by-pass.

It could be possible with a mill of 18 ft diameter and 32 ft length and 30 24-inch cyclones.

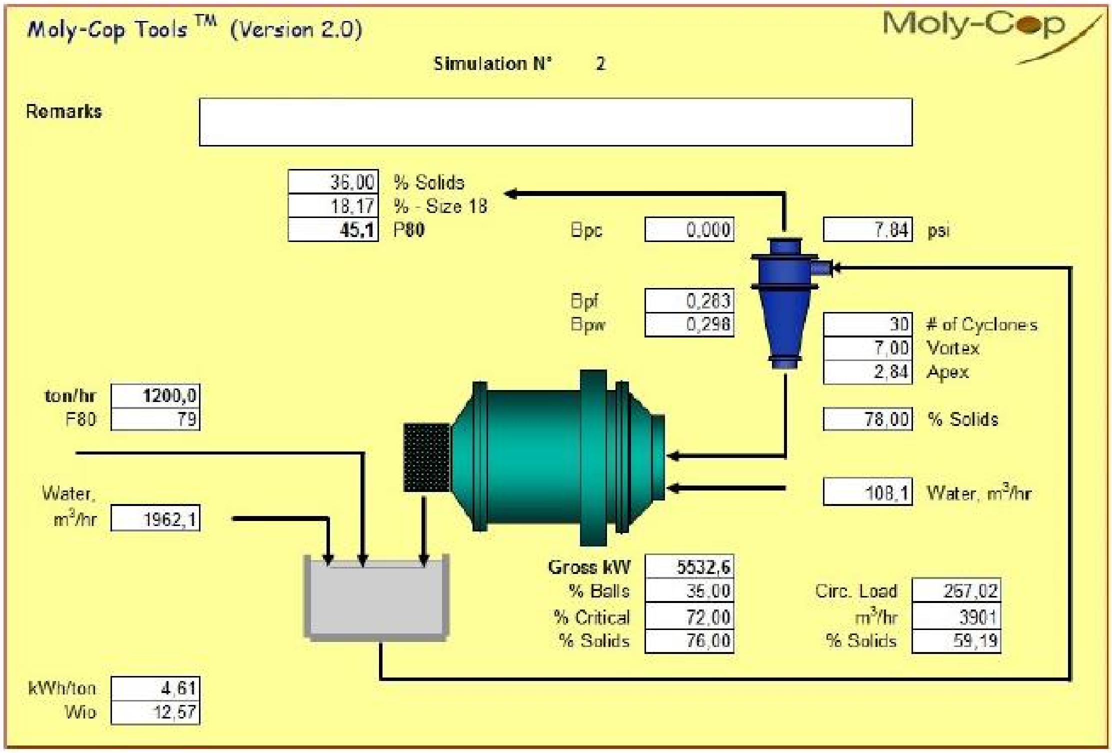

Figure 4: Mass balance – optimization

4. CONCLUSIONS

The grinding project is able to meet process demand with 4 mills with the cyclone adjusted. In addition to increasing the quantity and size, dilution (% solids) must be redefined. It is also estimated that the particle size is finer than the desired, can affect the regrind and flotation process.

The mill feed particle size is still under study with the HPGR manufacturer. Mill dimensions are according to the process and may not need changes. The grinding media diameter should also be more studied because it influence the particle size of the product affecting the other process.

The regrind process indicates many optimization possibilities, manly in case of energy consumption. The mill indicates an oversized project and the cyclones could be adapted too for a more efficient project.

5. ACKNOWLEDGEMENT

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