Comparing ball and vertical mills performance: An industrial case study

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ABSTRACT

The search for energy efficient technologies for comminution processes is constant in mineral processing studies, since those processes represent a major percentage of operational costs. In this context the use of stirred mills is increasing, especially for ultrafine grinding. Although many authors claim that these new equipment are more efficient than the conventional ball mills, there were very little chances to prove that in a practical way, since there are few industrial circuits where those technologies perform the same duty. Therefore, the regrinding circuit of Germano second concentrator offers an interesting opportunity: a vertical mill operating in parallel with two ball mills.

During almost two years of operation, several sampling campaigns were conducted to evaluate the vertical mill performance and to compare the operational data of the three mills. The industrial data was also compared to jar mill tests results, which are monthly conducted in Samarco labs in order to predict the specific energy consumption required by the ore fed to these circuits. The vertical mill demonstrated the same ability to achieve the product specifications of the ball mills while proved to be able to reduce the medium specific energy consumption in about 40%.

INTRODUCTION

Samarco is a Brazilian mining company with shareholding equally divided between Vale and BHP Billiton. Samarco acts in the international iron ore pellets market.

It has two industrial sites:

- one in the State of Minas Gerais, where Samarco carries out the mining and beneficiation activities (Germano – Mariana Municipality), in two Concentration Plants with a total production capacity of 24.0 million tons of concentrate per year;
- the other in the State of Espírito Santo, with three Pelletizing Plants and a total production capacity of 21.7 million tons per year and associated Port facilities (Ponta Ubu – Anchieta Municipality).

The sites are connected by two iron ore slurry pipelines approximately 400 km long each, with a combined transport capacity of 24.0 million tons of concentrate per year. Figure 1 shows the geographic location of Samarco's facilities.

Figure 1 Geographic location of Samarco's facilities.

The basic process flow sheet of both concentrators is the same which includes crushing, grinding, desliming, two stages of flotation, regrinding and thickening.

The second Germano concentrator started up in July of 2008 and reached its full production – 7.5 million tons of concentrate per year – just 6 months later. In 2010 some modifications were made to support an increase of production capacity of 1 million tons per year. Those modifications included a new flotation circuit and the installation of a vertical mill. Figure 2 shows the flow sheet for Germano concentrator II after these modifications.

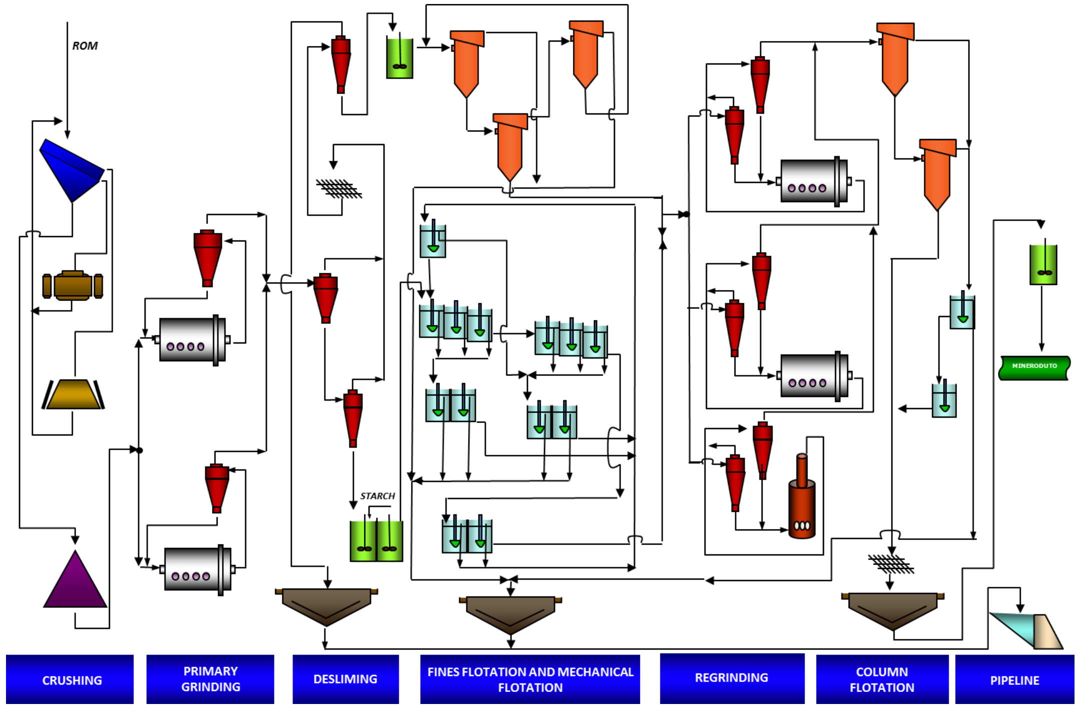

Figure 2 - Germano second concentrator flow sheet.

The vertical mill was installed as an alternative to increase the energy available in the regrind circuit. It was chosen due layout requirements: the difficulty to install a new ball mill in an operational plant with little footprint available was a key decision factor.

As can be seen in Figure 2, the vertical mill was set up in parallel with the two existing regrinding ball mills (18 x 33 ft, 6400 kW, each). The double classification system, which was applied before to the ball mills, was maintained. This system was applied to avoid a problem observed previously in concentrator I, where coarse silica was sent to the flotation columns due to the big difference between the density of gangue minerals (quartz) and iron ore ones (hematite and goethite). The vertical mill chosen was a VTM1500 (1500 cv) and it is fed with the concentrates of both fines and mechanical flotation circuits. A new slurry distribution system was provided to the circuit objecting the control of the feed rate for the new mill, since the energy distribution between it and the existing mills differs substantially. The vertical mill represented ten percent of the total power installed in the regrind circuit and, therefore, the system was designed to split the same percentage of total feed rate to this equipment.

Many authors claim that stirred mills have better performance than conventional grinding (Pena, 1992; Xiao et al., 2012; Brissette, 2009). In order to help in this assessment after the project commissioning a data set was collected to evaluate the new mill. The vertical mill was always compared to the other ones since Samarco had a rigid performance control of the existing ball mills. Both technologies are operating in parallel, which represented an important opportunity to compare them industrially. The results obtained from this comparison, are presented in this work.

METODOLOGY

Industrial data

The regrinding circuit of Samarco concentrators has three important goals:

- to liberate particles for the last stage of flotation;
- to prepare the material for filtering and pelletizing requirements: 88% passing in 44 microns (minimum) and 1800 cm^2/g (maximum);
- to prepare the ore concentrate for transportation trough pipelines: 97% passing 74 microns (minimum).

It was important to evaluate if the new mill could achieve all those specifications still maintaining the same (or lower) energy consumption observed on the ball mills.

This evaluation was based on industrial data obtained both from plant automatic control system and from manual sampling campaigns, those were conducted during the year of 2012.

Sampling campaigns were conducted in different moments for, at least, two operational regrinding lines, including the vertical mill and one ball mill line, for comparison. The following sampling points were taken:

- circuit fresh feed;
- feed, underflow and overflow from both classifying stages (cyclones).

All samples were collected during an hour with increments taken each 10 minutes, according to Samarco standard procedures. Industrial data such as mill power, cyclones feed pressure and mill feed rate were taken during the sampling campaigns. Particle size distribution and slurry density analyses were conducted to all samples to complete the program.

Grinding tests

Additionally to the sampling campaigns, industrial results were compared according to Samarco's methodology, based on grinding jar tests. Those tests were designed internally by Donda (2003) and have good correlation to industrial results as shown in Figure 3. The methodology was developed since traditional Bond tests weren't suitable to predict industrial mills behavior for itabirite ores. They are conducted monthly with industrial samples to evaluate plant performance.

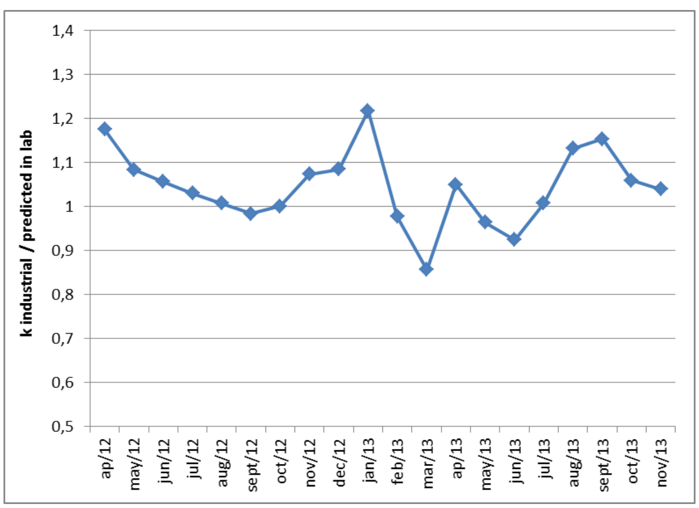

Figure 3 - Comparison between lab grinding tests results and industrial performance of ball mills.

The methodology consists of a series of jar tests made on a 10 x 10 inches mill, in different time intervals. The grinding time is converted in energy by Rowland equation for small diameter mills (Rowland, 1984). Grinding conditions are summarized on Table 1.

Table 1 Grinding tests conditons

Test variables	Conditions specified
Feed size	100% passing 1 mm
Mill dimensions	10" x 10" (0,2540 x 0,2540 m)
Mill rotation	65% of critical speed
Ball charge	18 kg, seasoned from 30 to 15mm
Mill filling	30,8% of mill internal volume
Percentage of solids in mill slurry feed	75% (weight)
Mass of sample per cycle	3,5 kg (for Samarco ore)

Figure 4 shows a typical grinding curve, obtained from Samarco grinding test:

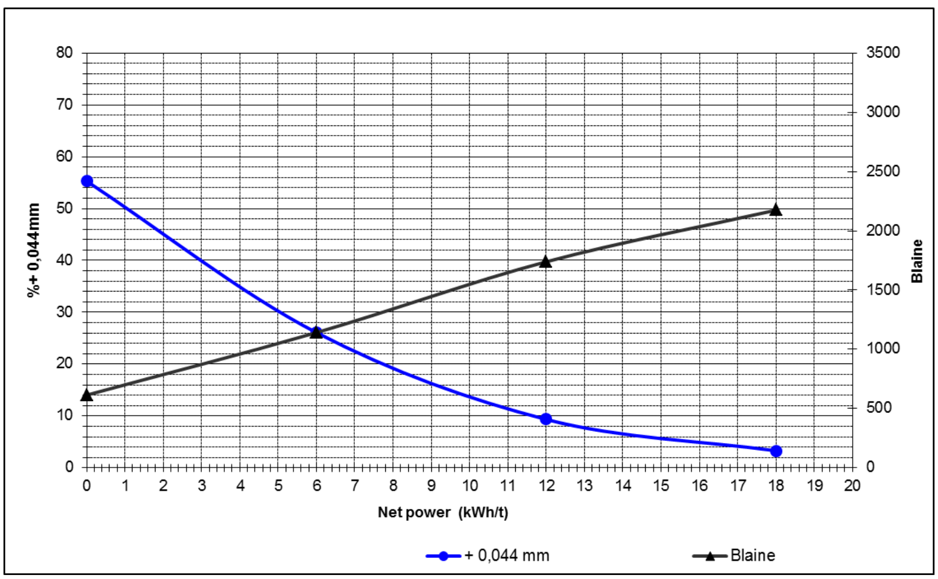

Figure 4 - Grinding curve.

The exponential grinding curve can be described by the following equation:

$$E = \frac{1}{k} \ln\left(\frac{\%F}{\%P}\right) \quad (1)$$

where,

E = specific energy consumption, kWh/t, net power;

%F = percentage retained in the feed on the sieve size used for circuit control;

%P = percentage retained in the product on the sieve size used for circuit control;

k = grinding parameter, depended on the ore characteristics and on the circuit conditions.

The k parameter (Donda & Rosa, 2013) was used to evaluate the vertical mill's performance, when compared to the ball mills.

RESULTS AND DISCUSSIONS

Energy consumption

Figure 5 shows the averages of net energy consumption per each mill in the regrind circuit on a monthly rate. The data was obtained from the automatic control system of the circuits. As can be seen, the vertical mill consistently presented lower net specific energy consumption than the ball mills which operate on the same circuit. The averages were 11.3, 11.7 and 6.5 kWh/t respectively for ball mill 01, ball mill 02 and vertical mill.

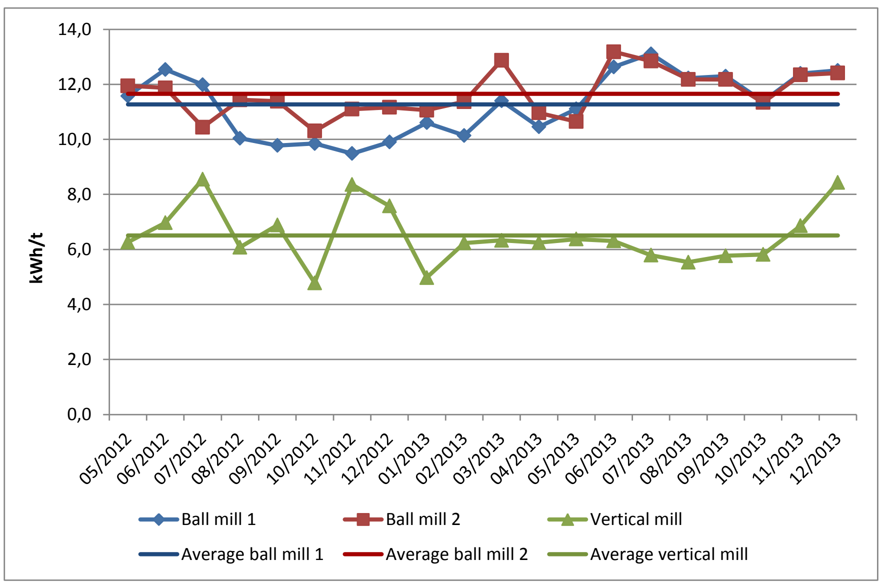

Figure 5 – Net specific energy consumption of regrinding circuit.

Nevertheless it's impossible to guarantee, industrially, that all the mills are fed by the exactly same material, especially considering that the high density of iron ore minerals makes slurry distribution more difficult. Besides, the products from the three mills were not the same which compromises the comparison simply by the specific energy consumption from each one. For the very same reason it was difficult to compare directly the product sizes distributions from the ball mills and from the vertical one. By general observation, it can be said that, since the fresh feed for each mill is reasonably similar, so are the product curves, as be seen in Figure 6.

Therefore it was used the k parameter, as explained before. Similarly to Bond Work Index, k parameter considers, besides the energy consumption, the sizes from mills' feed and product which normalizes the data from the three mills.

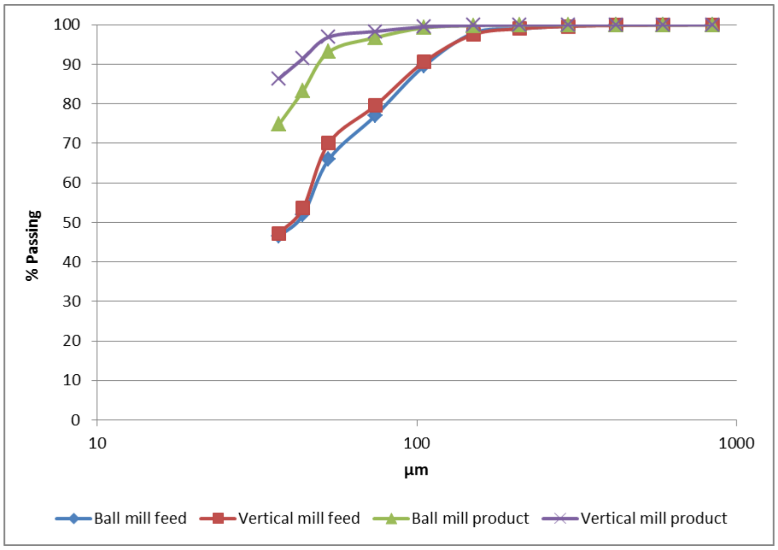

Figure 6 – Particle size distributions from ball mill and vertical mill circuits.

Since the automatic sampling system from concentrator II takes samples only from the combined streams on the regrinding circuit, a series of manual sampling campaigns were conducted along the year of 2012 to make this study possible. Figure 7 shows the results.

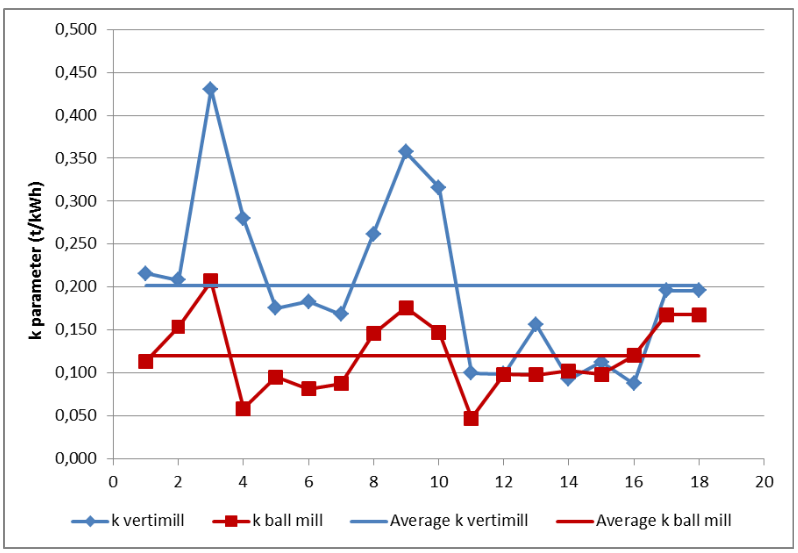

Figure 7 - Sampling results (k parameter).

As can be seen the samplings campaigns revealed a higher k parameter for the vertical mill in comparison to the ball mills sampled. This parameter represents the slope of the grinding curve which means the higher k, the easier to grind the material (or better performance for a grinding circuit). Therefore, the vertical mill showed performance significant better than the ball mills for the regrinding circuit of Germano concentrator II.

It's also possible to note in figure 7 that k from vertical mill decreased along the year, even reaching smaller values than those for ball mills in some points. This is due the wear of cyclones' apexes and, consequently, the increase on vertical mill circulating load, which reached values over 500% by the end of the year. Unfortunately, due to the difficulty to access the cyclones of the vertical mill, its maintenance was compromised. After the adequate maintenance of the cyclones, the performance of the vertical mill got better, which reinforces the importance of classification system role for the entire grinding circuit. Nevertheless it will be very valuable to keep monitoring the behavior of the regrinding circuit of concentrator II, in order to better evaluate the effects of operational parameters in the vertical mill performance.

Media consumption

The vertical mill was started up with a charge composed by media scrap, which was expulsed from the ball mills. It was expected a loss on mill's performance as predicted by grinding tests, showed on Figure 8.

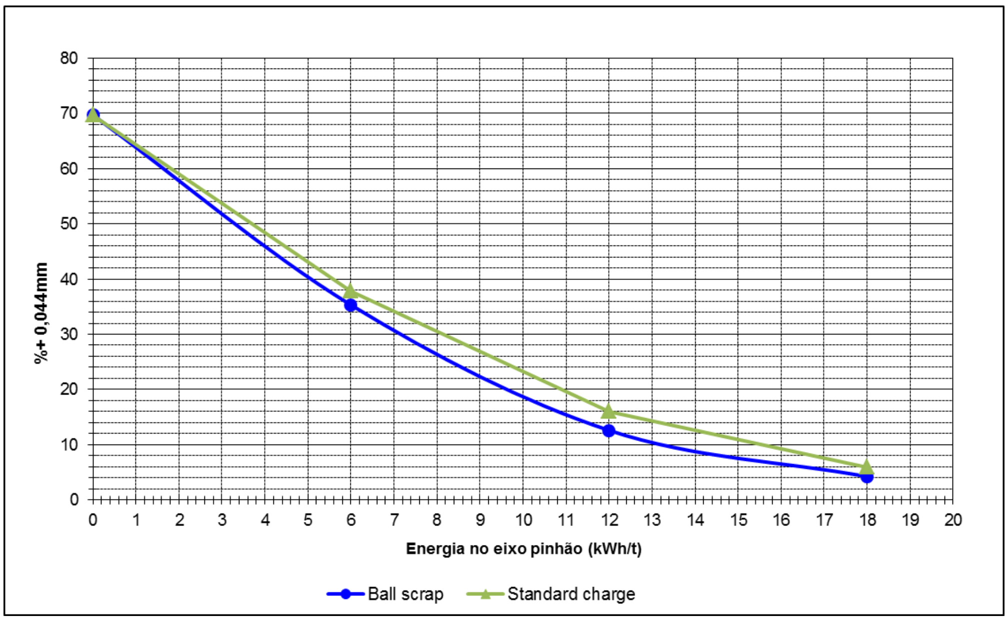

Figure 8 - Comparison to standard charge and balls scraps.

Thankfully, the performance of the vertical mill was still better than the ball mills, which reinforces the use of this technology.

But the use of scrap compromised the registration of media addition to the vertical mill making the control of media consumption impossible for a long period. Only by the beginning of 2013 this register was normalized. It was still not possible to observe any tendency, although smaller balls are employed in the vertical mill (smaller balls were added to the vertical mill after the sampling campaigns which are reported in this text). Figure 9 shows the media consumption for the three mills of the regrind circuit.

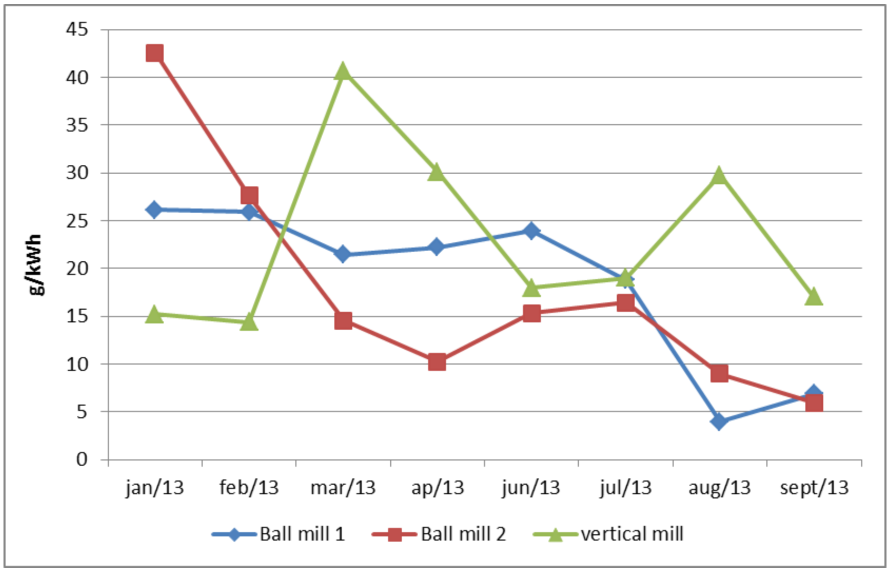

Figure 9 - Media consumption.

CONCLUSIONS

The comparison of industrial data showed that the vertical mill consistently presented lower specific energy consumption than ball mills operating in parallel to it, on the regrind circuit of Germano Concentrator II.

The grinding parameter k, which besides energy consumption takes in account the percentages retained on the grinding size for both feed and product of the circuit, also revealed better performance for the vertical mill in comparison to the ball mills.

Although those are encouraging results from a process point of view, mills' suppliers must work to make the maintenance easier and to produce machines of bigger capacity, in order to consolidate the use of this technology.

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