ASSESSMENT OF COMMINUTION ROUTES FOR ITABIRITIC ORE [1]

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Abstract

The progress and the deepening of iron ore pits demands the use of grinding processes to release iron ores from their veinstones and for the size adequacy required for the flotation process.

The high operational cost, marked by great power consumption in comminution operations, is the driving factor for conduction of comparative studies between comminution routes for iron ores, together with the need for minimizing lime production (increase in mass recovery) and simplifying comminution facilities.

The comminution route of itabiritic ore from Quadrilátero Ferrífero for pellet feed production was developed for three options: 1) Crushing in conventional circuit followed by ball grinding, 2) primary crushing, followed by semi-autogenous grinding (SAG) and ball grinding, 3) primary and secondary crushing followed by comminution using high pressure grinding rolls (HPGR) and ball grinding.

Tests in bench and pilot scales were run, and the produced results (chemical, size and mineralogical) were mathematically processed and validated using mathematic simulations.

Produced results have shown that comminution routes using HPGR and (SAG) instead of crushing stages tend to be more power-saving, in addition to simplify engineering flowcharts. The results produced using HPGR have pointed to a significant increase in lime production against other assessed routes.

Complementary studies and assessments, including comparative acquisition and implementation costs, operation and maintenance costs shall be run in order to conclude the comparative study between the comminution routes.

Keywords: itabirite, comminution, energy.

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1 INTRODUCTION

In ore processing, the fragmentation groups together a set of techniques aimed at reducing a solid of a given size to smaller fragments by means of external - and sometimes internal - mechanical action [(1)].

The fragmentation of the heterogeneous material which usually makes up rocks, aims at releasing valuable minerals from veinstones or, in case of homogeneous mineral, breaking it down to the required size for use [(1)].

The fragmentation comprises several stages applied to the ore, starting at the mine until its adequacy to the subsequent industrial process.

During the mining stage, ore or rock blasting may be considered as the first stage of fragmentation, as large-sized blocks of a proper to be fed into the crushing equipment [(1)] are produced.

Crushing is the operation that breaks down the blocks resulting from mining, but as there are several types of equipment, this operation must be repeated with different pieces of equipment until the proper material for grind feeding is produced [(1)].

Grinding is the operation of fine fragmentation which yields the proper product for concentration or any other industrial process (pelletizing, leaching, combustion, etc.) [(1)].

The importance of the fragmentation may be completely realized if considered that most energy spent in ore processing is consumed by this operation. We assume that fragmentation accounts for a large part the operational costs of an ore processing plant [(2)].

Erie Mining Co, in Minnesota (EUA), which processes taconitic iron ores is an example. As a result of fine scattering, this ore must be reduced to a size 90% below mesh 325. Energy consumption at the facility is given in Table 1 [(1)].

Table 1 – Distribution of the energy consumption at Erie Mining Co.

Operation	Kwh/t
Fragmentation	17.2
Concentration	1.5
Tailings disposal	1.2
Water supply	1.5
Total	21.4

As shown above, 80% of total energy required in the process is consumed by fragmentation, which shows the need for optimizing in order to decrease this consumption.

An ideal material breaks when its breaking point is crossed. That is, when all atomic bonds break. This can not be easily observed in rocks and minerals, as they are heterogeneous anisotropic materials and contain cracks and fractures both in micro- and macroscopic scale [3].

Considering the complexity of the fragmentation subject, not even the most useful studies conducted on rock fragmentation mechanisms, have yet yielded a satisfactory complete theory with practical application.

Since energy consumption in fragmentation represents the highest cost in an industrial facility, assessing it would be very valuable [1]. Therefore, the definition of a ratio that would allow the calculation of the energy required to fragment materials to a certain size is an old ambition of scientists and technicians.

Rittinger's Law:

The oldest of these relations is the one formulated by P. Ritter Von Rittinger[4] which states that "the area of the new surface produced by fragmentation is in direct proportion to the useful work consumed", as shown by Equation 1.

$$E = K(S_1 - S_0) \qquad (1)$$

where:
E = specific energy;
K = proportionality factor;
S_1 = product area;
S_0 = initial area;

This law is applied to very fine fragmentation, such as cement clinker grinding.

Kick's Law:

The second law was formulated by F. Kick [4]: "the required work is proportional to the decrease in volume of particles involved," expressed by equation 2.

$$E = CLog\left(\frac{D_0}{D_1}\right) \qquad (2)$$

where:
C = constant;
D_0 = initial diameter;
D_1 = final diameter;

This law is applied only to boulder crushing.

Bond’s Law

As Rittinger's and Kick's postulates did not comprehend all instances found in practice, and as the industry required some rules to sort materials according to response to fragmentation, F.C. Bond [5] formulated an empirical law often called "3rd Fragmentation Law." "Power consumed to decrease a material size is in inverse proportion to the square root of its size." He defined as size, the screen opening which 80% of the material would pass through.

$$E = E_0\left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}\right) \qquad 3$$

where:
E_0 = constant;
P = product size;
F = feed size.

Bond suggested the use of an index known as Wi (Work Index), defined as the work required to decrease the weight unit (short ton = 907 kg) of the referred material, given a theoretically infinite initial size ($F = \infty$) to an 80% passing size - in 100 µm - as shown by equation 4.

$$Wi = E_0\left(\frac{1}{\sqrt{100}} - \frac{1}{\sqrt{\infty}}\right) \qquad 4$$

$$Wi = \left(\frac{E_0}{\sqrt{P}}\right) \qquad E_0 = 10Wi$$

$$E = 10Wi\left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}\right) \qquad 5$$

The application of Bond's equation for the calculation of consumed energy at a grinding facility has spread out, and Wi experimental assessment currently is a rule of thumb for many laboratories (1).

2 MATERIALS AND METHODS

The activities performed during this paper, starting with the sample formation for tests in the three assessed comminution routes are shown in figure 1 below. The produced results were interpreted using size, chemical and mineralogical analyses. The produced results were also analyzed using mass balances and simulations.

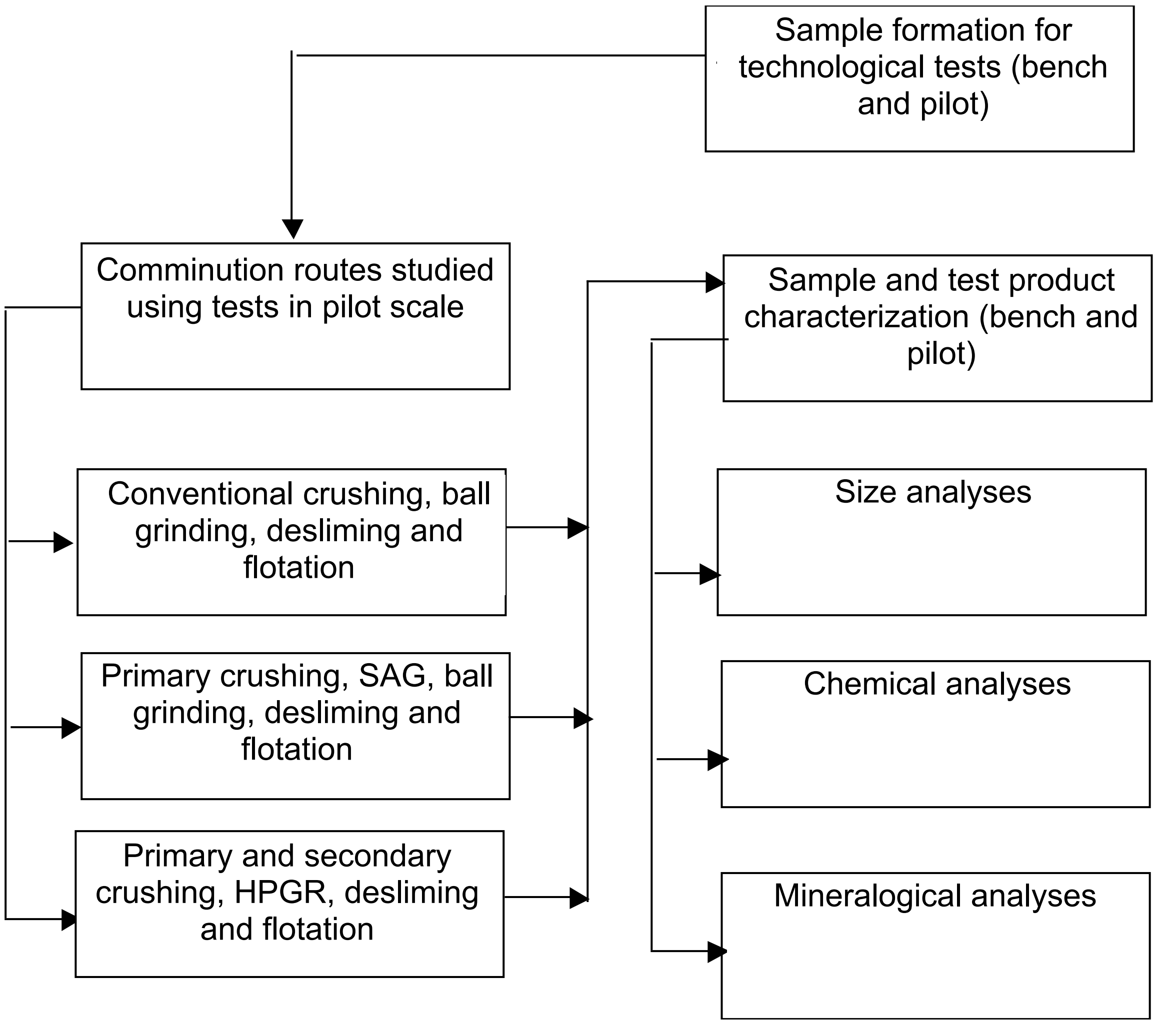

Figure 1- Work stage flowchart

The conventional crushing route was made in four crushing stages (primary, secondary, tertiary and quaternary), with a 12, 7 mm top size (P_{95}) product as the result used to feed the ball grinding stage.

The SAG was fed using material crushed at 8" (primary crusher) and screened at 12.7 mm.

The HPGR was fed using two types of feed (primary and secondary crushing products): -31.5mm total and –31.5+12.7 mm.

The crushing tests in conventional circuit, ball grinding, desliming and flotation were made at the pilot plant located at Vale's Center for Technological Researches, in Mariana, MG. The SAG tests were made at the CETEM pilot plant located in Paragominas, PA and comminution tests in HPGR were made at Vale's pilot grinding rolls in Vitória, ES.

All tasks were performed together with the consultants Cláudio Schineider and Homero Delboni.

3 RESULTS AND DISCUSSION

The sample size distribution (ROM) is shown in figure 2 below and Table 2 has its size/chemical analysis.

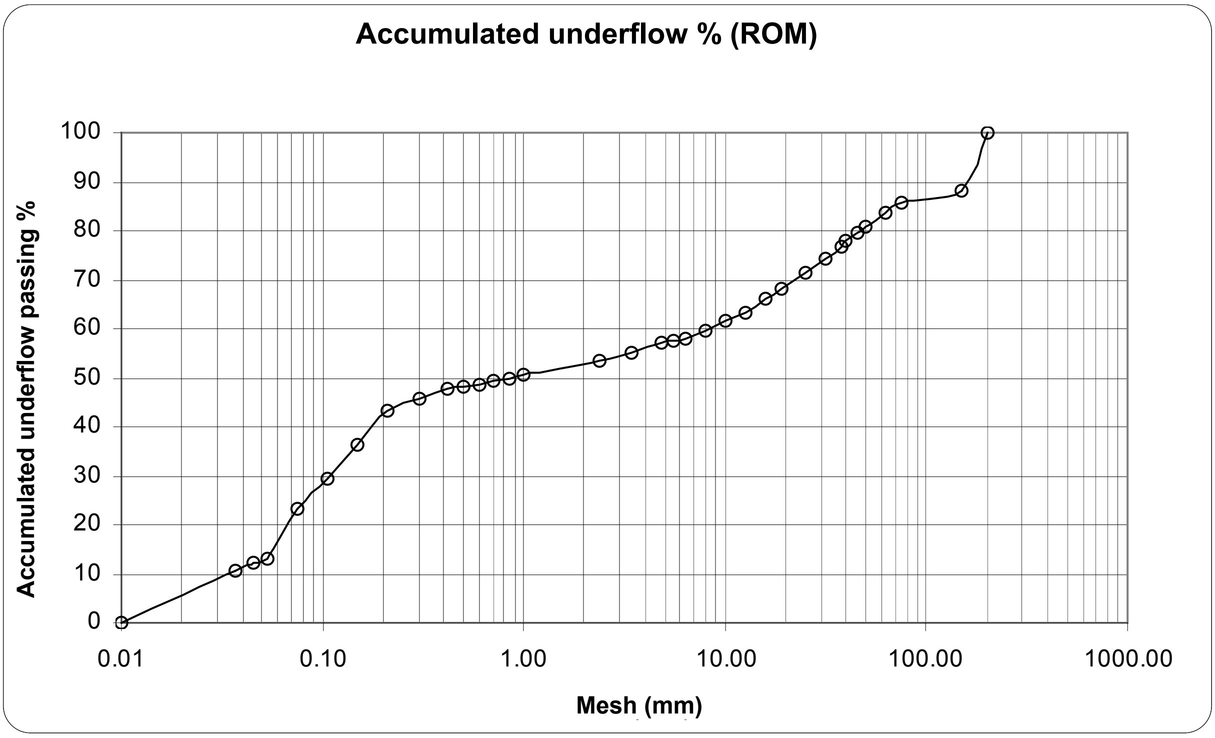

Figure 2- ROM size distribution

Table 2- ROM size/chemical distribution

Mesh (mm)	Mass (%)	Fe (%)	SiO_2 (%)	Al_2O_3 (%)	P (%)	PPC (%)
-200+150	11.892	29.81	56.06	0.30	0.029	0.16
-150+75	13.401	43.49	36.09	0.56	0.016	0.40
-75+25.4	8.967	48.18	29.91	0.46	0.013	0.38
25.4+12.7	6.493	48.90	28.20	0.81	0.014	0.69
-12.7	59.248	38.15	42.31	1.45	0.015	0.89
Global	100.000	39.47	41.08	1.06	0.017	0.68

Figure 2 shows that the studied itabirite sample has approximately 40% of material retained at 8.0 mm mesh and 36% underflow through the mesh 0, 150mm. The global Fe content was 39.5%.

This sample was then submitted to three comparative comminution routes, as described below.

The comparative size distribution for products resulting from the three comminution routes (conventional crushing, SAG, HPGR with –31.5mm feed and HPGR with –31.5+12.7 mm feed) is shown in figure 3 below. These sizes refer to feeding during the ball grinding stage.

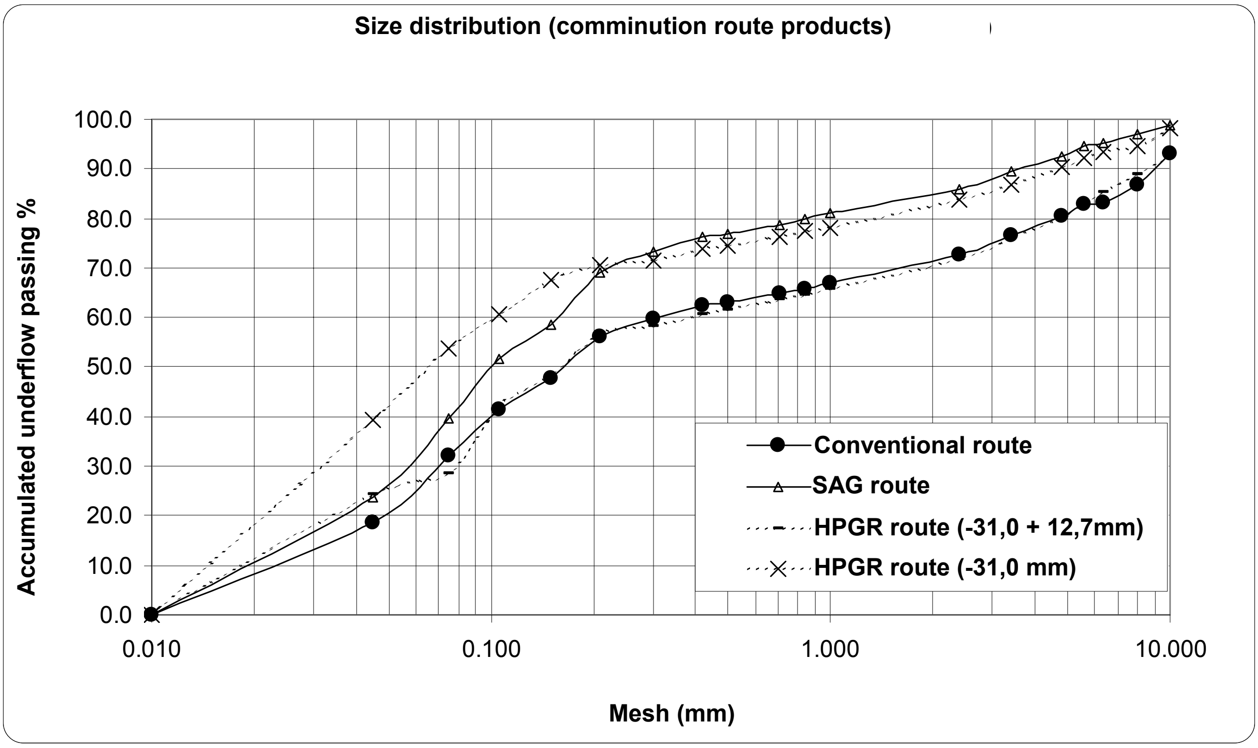

Figure 3- Size distribution of products resulting from comminution routes

Figure 3 above shows that the HPGR route fed with a –31.5 mm fraction produced the greater percentage of fines (67.46% < 0.150 mm). The HPGR route with –31.5+12.7 mm fraction produced a quite similar size distribution compared to the conventional crushing route, yielding a greater percentage of particles below 0.045 mm (24.25% against 18.7% in the conventional route).

The products resulting from the above mentioned comminution routes were submitted to ball grinding and desliming pilot tests, as shown by the results in Table 3.

Table 3- Comparative results in ball grinding and desliming

Parameter	Conventional route	SAG Route	HPGR route (-31, 5 mm)	HPGR route (-31, 5+12, 7 mm)
% lime	12.06	12.04	21.37	16.93
Specific energy in grinding (kwh/t)	13.30	9.39	10.62	10.62

Table 3 above shows that the comminution route which used HPGR followed by ball grinding tends to produce more mud. When the press is fed using the –31.5+12.7 mm fraction (scalped sample) lime production is reduced, but it is still higher than the other two assessed routes. Conventional and SAG crushing routes followed by ball grinding produced the lowest percentage of mud (approximately 12% for these two routes).

The results of the simulation indicate the possibility of decreasing lime production with changes in the sorting circuit of grinding products, such as using a double cycloning stage.

The energy consumption during the grinding stage was measured during tests in a pilot scale. Table 3 suggests that the conventional crushing product tends to cause greater specific consumption at the ball grinding stage.

4 CONCLUSION

The assessment of comminution routes of itabiritic ore indicates greater lime production for the route using HPGR, followed by ball grinding. The lime percentage may be decreased by using a sorting stage prior to the grinding rolls (scalped sample: -31.5+12.7 mm). Even with the scalped sample, the grinding rolls route indicates greater lime production. The possibility of decreasing lime production is indicated by changes in the sorting circuit of grinding products.

The comminution routes using HPGR and SAG tend to cause the lower specific energy consumption during the ball grinding stage.

The final decision for the choice among the comminution routes shall take other parameters into account: implementation, operation and maintenance costs, flowcharts and layout.

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AVALIAÇÃO DE ROTAS DE COMINUIÇÃO PARA UM MINÉRIO ITABIRÍTICO [1]

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RESUMO

O avanço e aprofundamento das cavas de minérios de ferro têm levado à necessidade de aplicação de processos de moagem para liberação entre os minerais de ferro e suas gangas e adequação granulométrica necessária ao processo de flotação.
O elevado custo operacional, destacado pelo elevado consumo energético das operações de cominuição, tem sido a motivação para a realização de estudos comparativos entre rotas de cominuição para minérios de ferro, aliado ainda à necessidade de minimização de geração de lamas (aumento da recuperação em massa) e simplicação das instalações de cominuição.
A rota de cominuição de um minério itabirítico do Quadrilátero Ferrífero, visando a produção de "pellet feed", foi desenvolvida para três opções: 1) britagem em circuito convencional seguida de moagem de bolas, 2) britagem primária, seguida de moagem semi-autôgena (SAG) e moagem de bolas, 3) britagens primárias e secundária, seguidas de cominuição utilizando prensa de rolos de alta pressão (HPGR) e moagem de bolas.
Foram realizados testes em escalas de bancada e piloto, sendo os resultados obtidos (químicos, granulométricos e mineralógicos) tratados matematicamente e validados por simulações matemáticas.
Os resultados obtidos mostraram que as rotas de cominuição utilizando prensa de rolos de alta pressão e moagem semi-autôgena (SAG) substituindo etapas de britagem tendem a ser energeticamente mais econômicas, além de simplificação de fluxogramas de engenharia. Os resultados obtidos utilizando prensa de rolos de alta pressão indicaram aumento significativo na geração de lamas em relação as outras rotas avaliadas.
Estudos e avaliações complementares, incluindo custos comparativos de aquisição e implantação, custos de operação e manutenção, deverão ser realizados para conclusão do estudo comparativo entre as rotas de cominuição.

Palavras-chave: itabirito, cominuição, energia.

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