

ABRASIVENESS EVALUATION OF PRE-CONCENTRATION OF COPPER SULFIDE ORE PRODUCTS THROUGH LCPC TEST

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Abstract

Ore abrasiveness is usually quantified through the Bond Abrasiveness Index (AI), which is based on the capability of a material wearing out and polishing other materials. This index finds widespread application in the assessment of how much wear a given ore is set to cause in ore processing equipment. Several test methods may be used to determine ore abrasiveness, but the Bond Method is the one most frequently used in the mining industry. Despite being simple, this test has certain limitations as to grain size and required amount of ore sample, which very often makes it difficult or even impossible to apply it in the early stages of a project, geometallurgical and pre-concentration laboratory studies. The LCPC test may offer an alternative, as it requires a smaller amount of fine-grained material. The core objective of this study is to use the LCPC test to evaluate the abrasiveness index of a copper sulfide ore that went through a pre-concentration process. One of the findings is that the pre-concentration process produced a concentrate whose abrasiveness is lower than that of the feed, which helps enhance the pre-concentration gains, in addition to the expected gain by reducing the mass and increasing the grade of ore to be fed into the mill.

Keywords: Bond Abrasiveness Index (AI); Abrasiveness; Wear; LCPC; Pre-concentration.

AVALIAÇÃO DA ABRASIVIDADE DOS PRODUTOS DE UMA OPERAÇÃO DE PRÉ-CONCENTRAÇÃO DE UM MINÉRIO SULFETADO DE COBRE A PARTIR DO ENSAIO LCPC

Resumo

A Abrasividade de um minério, quantificada normalmente pelo Índice de Abrasividade de Bond (AI), se refere à capacidade de um material desgastar ou polir outros materiais. O AI é amplamente utilizado para avaliar o desgaste que determinado minério causará no revestimento dos equipamentos dos processos de beneficiamento. Diversos ensaios podem ser realizados a fim de se determinar a abrasividade, sendo o Método de Bond o mais utilizado na indústria de mineração. Apesar de simples, tal ensaio apresenta algumas limitações em relação à granulometria e quantidade de minério necessário, o que muitas vezes dificulta, ou mesmo impossibilita, sua execução com minérios em etapas iniciais de projeto, estudos de geometurgia e em estudos de pré-concentração. O ensaio LCPC pode se constituir numa alternativa para a avaliação desses minérios, pois requer uma menor massa de material com granulometria mais fina. O objetivo principal do trabalho apresentado neste artigo é avaliar o índice de abrasividade de um minério sulfetado de cobre, que passou por um processo de pré-concentração, utilizando-se o ensaio LCPC. Foi possível observar que a pré-concentração resultou em um concentrado de abrasividade menor que a alimentação, o que ajuda a potencializar os ganhos da pré-concentração, além do ganho já esperado de redução da massa e aumento do teor que irá alimentar a usina.

Palavras-chave: Índice de Abrasividade de Bond (AI); Abrasividade; Desgaste; LCPC; Pré-concentração.

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*Versão revisada de trabalho apresentado na ABM Week 2017, de 2 a 6 de outubro de 2017, São Paulo, SP, Brasil.



I INTRODUCTION

Ore pre-concentration is a well-known process that enables significant gains in terms of increasing the metal content of feed in ore processing mills – which may lead to increasing reserves, reduced ore mass that needs to be processed to produce the same amount of metal, and the possibility of generating coarser tailings, whose disposal is simpler and more economical than the disposal of fine tailings, which require large tailings dams [1]. In Brazil, pre-concentration had already been adopted in Nitroquímica's fluorite mine in Morro da Fumaça, state of Santa Catarina [2], which was shut down in 2009. Currently, it is used on an industrial scale at Largo Resources' vanadium mine in Maracás, state of Bahia. Laboratory and pilot-scale evaluations of a number of copper, nickel, zinc, and lead sulfide ores [1,3,4] in Brazil have shown significant gains in terms of higher metal content and metallurgical recovery, resulting in the disposal of around 50% of the feed mass as tailings, which retain less than 10% of the overall metal content in ores fed into the pre-concentration process.

Notwithstanding the apparent benefits, the implementation of pre-concentration circuits requires expensive investment. In many cases, the pre-concentration implementation costs are not paid back by the expected operational gain, according to evaluations based on pilot plant and laboratory data. Nevertheless, it should be pointed out that such feasibility calculations do not take into account gains that could stem from reduced Bond Work Index (BWI) and Bond Abrasiveness Index (AI) in the material to be fed into the mill, as the pre-concentration eliminates a large amount of gangue, which usually features higher competence and causes more intensive wear in equipment lining and grinding balls. However, carrying out such an assessment is not always a simple task, particularly in the early stages of a project. In laboratory pre-concentration tests, for instance, it is difficult

to obtain the necessary mass and grain size for the Bond AI test, which is currently the most frequently used test method in the mining industry [5]. Moreover, differences in grain size between the concentrate and the pre-concentration tailings often occur due to stratification during the jiggling process. Such stratification may lead to inconsistent AI results, as illustrated in [4]. Therefore, it is important to find an alternative to the Bond test method to carry out this evaluation.

The LCPC test is an alternative method to assess the abrasiveness of materials with finer particle size. While the Bond AI Test described by Bergstrom [6] requires 1,600 g of ore with a grain size ranging from $\frac{3}{4}$ " to $\frac{1}{2}$ ", the LCPC test is carried out with just 500 g of material with much finer grain size, i.e. from 4 to 6.3 mm. This test method was developed by France's *Laboratoire Central des Ponts et Chaussées* in the 1980s [7]. The LCPC Index may be used as a measure of both abrasiveness and the ore crushability. The corresponding test procedures are defined by the French standard P18-579 [7].

In addition to being widely used in Europe [8-12], the reason for choosing the LCPC method was mainly the requirement for a lower mass of material and a smaller grain size than those required by the Bond AI method, which are the main restrictions to the latter in applications to assess the abrasiveness of pre-concentrated ores. Figure 1 illustrates the results achieved by [13], showing the correlation between AI results provided by the Bond and LCPC methods.

The core objective of this research was to use the LCPC test method to determine the abrasiveness index of a copper sulfide ore after a pre-concentration stage. As a result, additional inputs are expected to be provided for the economic feasibility evaluation of pre-concentration projects, which would lead to a more accurate assessment of this alternative.

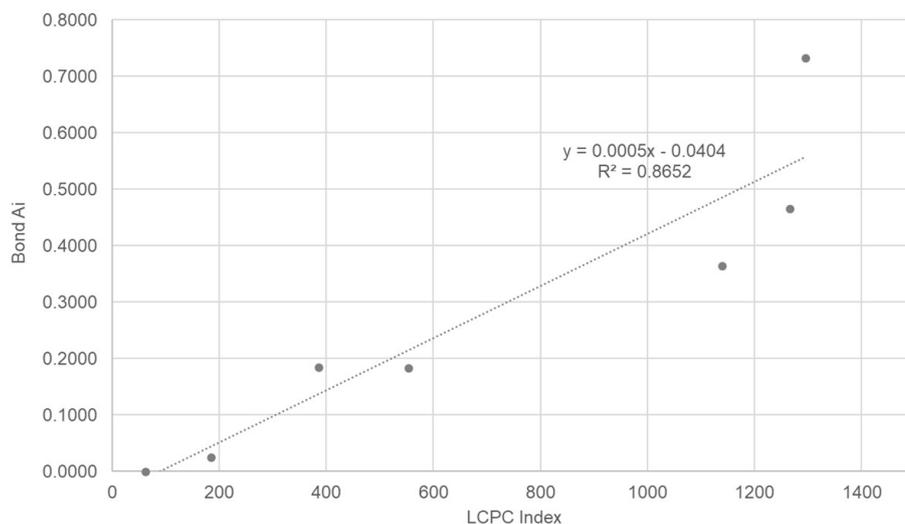


Figure 1. Correlation between Bond AI and LCPC [13].

2 MATERIALS AND METHOD

Copper sulfide ore from Mineração Caraíba S/A's Boa Esperança Project, state of Pará [14], was used in this study. Samples were taken from the product of a jigging pre-concentration trial carried out on material with particle size ranging from 3 to 10 mm. Details of the jigging process are described in [3]. The samples were weighed and prepared to obtain the required test mass (500 g) with a grain size between 4 and 6.3 mm. Sample characterization was based on X-ray fluorescence (FRX) and X-ray diffraction (DRX) techniques, at LCT/USP.

The LCPC tests were carried out according to the test procedures set out by the French standard P18-579. The abrasion equipment consists of a motor that rotates a metal plate inside a cylindrical recipient containing 500 g of sample with a grain size between 4 and 6.3 mm. The standard metal plate is manufactured from low carbon steel (C1015), 50x25x5 mm in size, with Rockwell hardness from 60 to 75 HRB. The rotor to which the metal plate is coupled rotates for five minutes at 4,500 rpm inside the sample recipient. Abrasiveness is determined by weighing the metal plate before and after the test. The recorded loss of mass is used to calculate the characteristic material abrasiveness. The higher the loss of mass, the more abrasive the material. Figure 2 illustrates the equipment.

As set out in the French standard, the LCPC abrasiveness index is calculated according to Equation 1:

$$\text{LCPC} = 1000 \times 1000 (m_{ip} - m_{fp}) / M \quad (1)$$

where: m_{ip} is the plate mass prior to the LCPC test; m_{fp} is the plate mass after the LCPC test; and M is the sample mass (500 ± 0.2 g).

Prior to commencing the tests, the test metal plates were submitted to Rockwell B hardness tests and measurements at IPT, to ensure that their hardness met the applicable requirements. Such preliminary tests indicated that the LCPC test plates had a 65 HRB average hardness, therefore falling within the 60 to 75 HRB range as defined by the French standard. Care was taken to use plates from the same lot and manufacturer in all tests, with an aim to prevent possible manufacturing variations from affecting the test results. Moreover, all samples were submitted to duplicate or triplicate tests to minimize the influence of possible test errors.

3 RESULTS AND DISCUSSION

Table 1 gives the chemical and mineralogical characterization results for the ore samples (jigging pre-concentration feed, concentrate and tailings) used in this study.

It should be noted from Table 1 that pre-concentrating copper sulfide ore produced a concentrate whose SiO_2 content is significantly lower than the feed, i.e., the pre-concentration tailings are enriched in SiO_2 bearing minerals, mainly quartz.

Table 2 shows the abrasiveness test results for the feed, concentrate, and tailings of copper samples that underwent a pre-concentration process through jigging.

One of the aspects that can be evaluated through the results given in Tables 1 and 2 is the relation between the

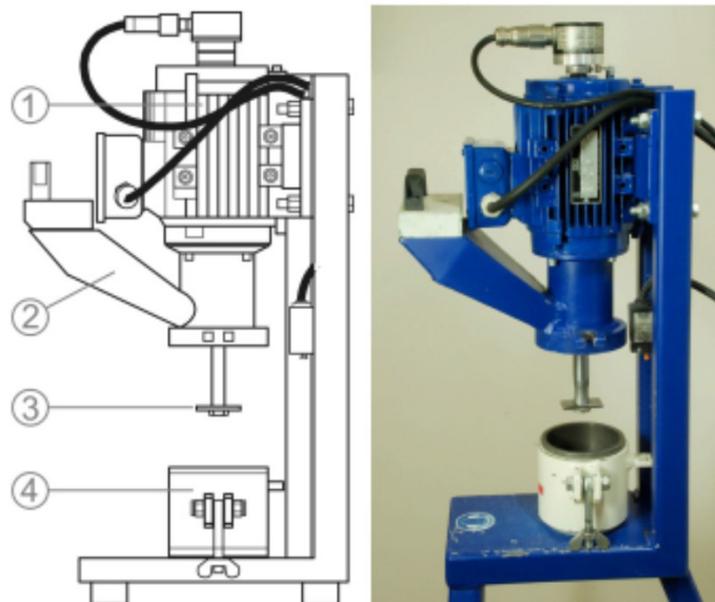


Figure 2. LCPC Equipment (1) motor; (2) funnel tube; (3) steel impeller; (4) sample container [12].

Table 1. Chemical and mineralogical characterization of copper ore samples

Sample	Mineralogical composition (predominant phases)	Mass (%)	Component concentration (%)		
			Cu	SiO ₂	Fe ₂ O ₃
Feed	Quartz, pyrite, magnetite and chalcopyrite	100	0.75	54.2	15.7
Concentrate	Chalcopyrite, quartz, pyrite and magnetite	44	1.45	40.5	25.0
Tailings	Quartz, albite, chlorite, microcline and mica	56	0.20	65.0	8.4

Table 2. LCPC Index determined for pre-concentrated ores

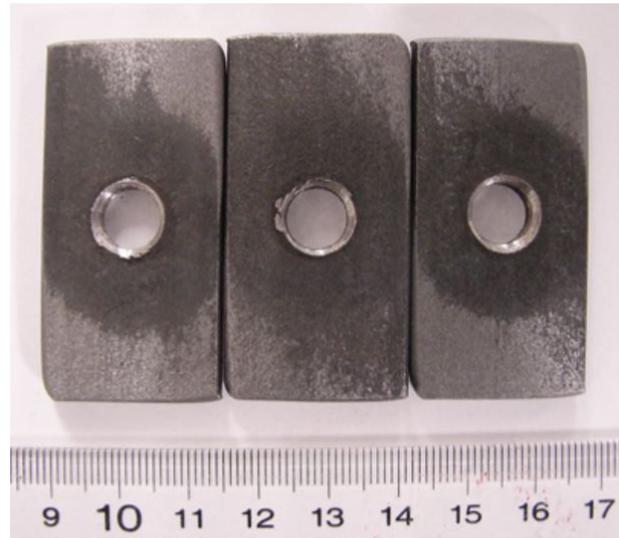
Sample	LCPC Index	Average LCPC Index
Feed	1086	1059
	1046	
	1044	
Concentrate	865	782
	692	
	819	
	752	
Tailings	1124	1105
	1100	
	1092	

silica content in the sample and the ore abrasiveness. It is notable that the highest LCPC Index values were obtained in samples with the highest silica contents. Based on the results shown in Table 2, one can conclude that, from the standpoint of ore processing, it would be advantageous to carry out the feed pre-concentration prior to the grinding stage. As can be seen from Table 2, this is due to the fact that the concentrate abrasiveness is approximately 25% lower than that of the feed, which would entail lower wear on crushing and grinding facilities and, as a result, lower beneficiation costs.

In addition to the abrasiveness data, it was also possible to visually assess the test plate wear rates for the different materials tested. Figure 3 clearly shows that the middle plate (corresponding to the pre-concentration product) is much less worn than the other two test plates, which confirm the results that the pre-concentration product has a lower abrasiveness index compared to the feed and pre-concentration tail. Moreover, it can be seen that the most intensive wear occurred on the third test plate, which corresponds to the tailings, the most abrasive material according to numerical results.

4 CONCLUSION

This study provided evidence that the LCPC test was effective in determining the abrasiveness of the feed and products of a copper sulfide ore pre-concentration operation. In addition to the well-known gains from pre-concentration processes in terms of reduced mass to be fed into the mill,

**Figure 3.** Plates used in LCPC tests of copper sulfide ore samples (from left to right: feed, concentrate, and tailings).

the abrasiveness assessment indicated a significant reduction (approximately 25%) in abrasiveness of concentrate produced by the pre-concentration operation. This means a remarkably lower consumption of equipment lining and grinding balls, which should be taken into consideration when analyzing the economic feasibility of projects involving a pre-concentration stage. Moreover, the LCPC Index made it possible to quantify the expected abrasiveness through a coefficient that is correlated to the most frequently used Bond AI, albeit in a faster way, using a finer-grained material and requiring a smaller sample mass.

Acknowledgements

Our special acknowledgment to Fundação do Instituto de Pesquisas Tecnológicas do Estado de São Paulo S/A for having financed this project through the invitation to bid no. 08/2016. They also like to thanks Mineração Caraíba S.A. for the samples supplied for this study and CNPQ for the financial support for this project (research project 449932/2014/1 and CT2016 – 308767/2016-0).

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Received: 15 Nov. 2017

Accepted: 21 Mar. 2018