Development of a laboratory test for wear prediction in ore processing circuit

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ABSTRACT

The abrasiveness of a mineral or rock is an extremely important topic in the mining industry and is generally measured by the Bond abrasion index (AI). However, to determine such an index by the Bond test requires 1,600 g of sample with particle sizes ranging from ½" to ¾", which are not available in certain situations, such as ore prospecting, drilling, and geometallurgical studies. In order to investigate the abrasiveness of smaller-sized sample materials, a modified LCPC test was developed, which allows testing fine materials (i.e., 1.0 mm or smaller) to predict wear in ore processing circuits and anticipate possible failures resulting from changes in abrasive characteristics of the ore being processed. The results for 16 different materials indicated a good correlation with the AI and the modified LCPC, resulting in a reliable alternative for the AI.

Keywords: Bond Abrasion Index (AI), LCPC, abrasiveness

1. Introduction

The abrasiveness of an ore or rock is a major issue for the mining industry and has been studied by various authors, with emphasis on the sizing and selection of equipment and materials used in the manufacture of ore processing and handling machinery (Giblett and Seidel, 2011; Drucker, 2011; Albertin and Sinatora, 2011; Bond, 1963; Morell, 2019 and Massola, Chaves and Albertin, 2016). Abrasiveness is the ability of a material – in this specific case a piece of ore or rock – to polish, clean, or wear out other materials, which is the most common wear mechanism in industrial equipment (Albertin and Sinatora, 2011 and Massola, Chaves and Albertin, 2016). Therefore, it is necessary to investigate such wear mechanisms and how to measure abrasiveness using quick, accurate, and reliable methods.

The Bond abrasion test (Bond, 1963) is currently the method most commonly used by the mining industry to measure this parameter. Although this method is a benchmark in the industry, it requires 1,600 g of sample with particle size ranging from ½ " to ¾" and takes approximately 60 minutes to be carried out. The LCPC test has been developed as an alternative to the standard Bond test. Standardized by a French standard (Afnor, 2013), it requires a feed sample of only 500 g of material with particle size from 6.3 mm to 4.0 mm and can be conducted in five minutes. Metso (2008) and Peres, Massola and Bergerman (2018) illustrate the good correlation between Bond AI and LCPC results. Several authors describe the application of LCPC in the mining industry and address the variables that may have an impact on the test (Drucker, 2011; Metso, 2008; Kasling and Thuro, 2010; Thuro et al., 2007; Hamzaban et al., 2019 and Peres, Massola and Bergerman, 2018).

The approximately twelve-fold shorter test time (5 minutes for the LCPC test versus 60 minutes for the Bond test) and the approximately three times smaller mass (500g in the case of LCPC versus 1600g in the case of Bond) are remarkable advantages (Bond, 1963, Afnor, 2013). Nevertheless, particle size remains a limiting factor when it comes to determining the abrasiveness of ores in pre-concentration and geometallurgy studies, or the abrasiveness of prospecting, drilling, comminution, and flotation products, as in such cases the particle sizes are too small for the LCPC or Bond AI tests. For this reason, this study proposes a new method as an alternative to the LCPC, using materials with particle size below 4.0 mm, e.g., 3.35 mm to 2.36 mm and 1.70 mm to 0.85 mm. This test method will enable predicting the wear in ore processing equipment, and consumables, which allows anticipating possible failures and higher operating costs resulting from changes in abrasiveness characteristics of the ore being processed.

2. Experimental

The study was based on crushed stone samples with different particle sizes and abrasiveness larger than 1" supplied by different mines in Brazil, including Vale Salobo and Sossego copper mines (11 samples) and Embu S.A. aggregates mines (5 samples). The samples were first crushed and sieved to fit the standard ½" to ¾" particle size range as required by the Bond abrasion test. The resulting material was arranged in long piles and quartered to produce 1,600-g samples, which were subsequently partitioned into four 400-g fractions as required by the same test. Next, the remaining sample was crushed to fall within the 6.3 mm to 4 mm (standard LCPC), 3.35 mm to 2.36 mm and 1.70 mm to 0.85 mm (modified LCPC) particle size range required for the LCPC abrasion test and samples were prepared, each weighing 500 ± 0.2 g. Around 2 kg of the five samples received from Embu were prepared for chemical and mineralogical analysis in order to confirm that the material used for the Bond Abrasion and LCPC tests were similar in terms of mineral composition.

Initially, tests were performed on samples of standard particle size according to the Bond and LCPC test methods (Bond, 1963 and Afnor, 2013) aimed at validating the correlation between both methods. Next, tests were performed on finer particle size samples for the development of an alternative to the LCPC test, while keeping all test parameters other than particle size unchanged. The LCPC and Bond tests were carried out at the Ore Processing Laboratory of the Department of Oil and Mining Engineering, University of São Paulo (LTM-PMI-EPUSP).

The Bond Abrasion Index is based on the percentage difference between the masses of the steel plate after and prior to the test, illustrated in Equation 1.

$$AI = (M_{final} - M_{initial}) / 100 \quad (1)$$

Where $M_{initial}$ and M_{final} are the plate masses before and after the test. The resulting Bond AI always falls between 0 and 1 and indicates how abrasive the tested material is: the closer to 0, the less abrasive the material.

As in the case of the Bond abrasion test, the wear plate is weighed before and after the LCPC test and the LAC abrasion index is calculated according to Equation 2.

$$LAC = 1000 \text{ x } 1000 \text{ x } (M_{final} - M_{initial}) / M_{sample} \quad (2)$$

Where $M_{initial}$ and M_{final} are the steel plate masses before and after the test and M_{sample} is the mass of material used in the test (500 ± 0.2 g). The higher the LAC index, the more abrasive the material.

Steel wear plates used in the abrasion tests were also subjected to hardness tests to confirm their compliance with standards stipulating test conditions applicable to the LCPC and Bond test (Bond, 1963, Afnor, 2013). Such tests were carried out on a Rockwell durometer at the São Paulo State Institute for Technological Research (IPT-SP).

3. Results and discussion

Bond and LCPC tests using standard particle sizes confirmed the good correlations determined by Metso (2008) and Peres, Massola and Bergerman (2018), as shown in Figure 1.

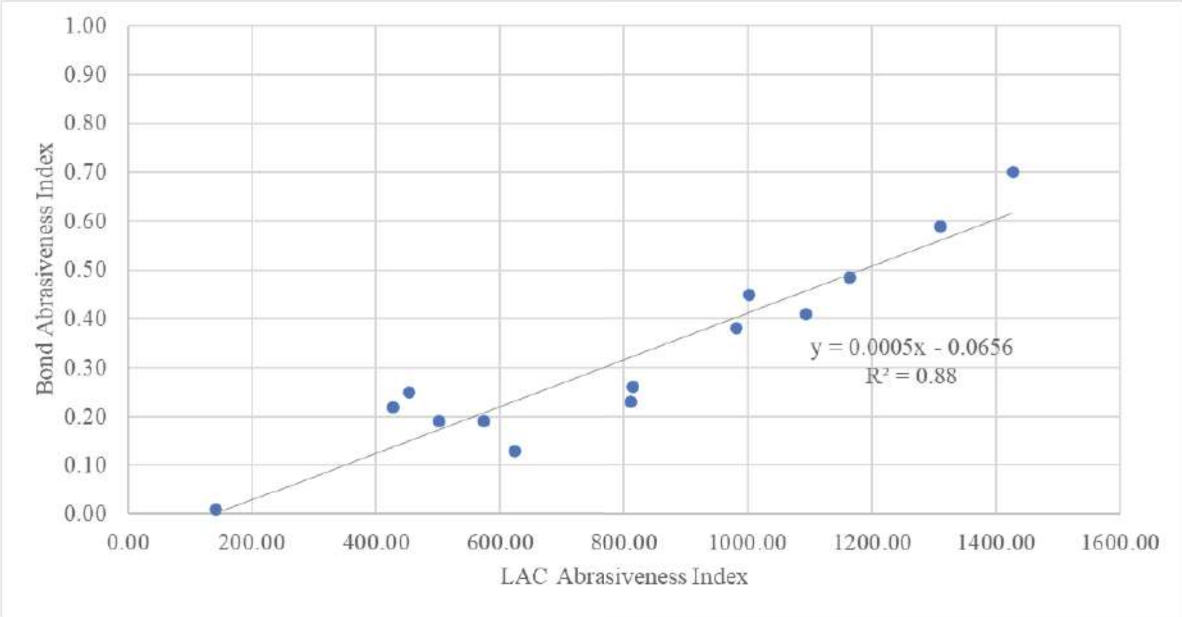

Fig. 1. Correlation between LCPC and Bond AI in the validation stage

The results of the modified LCPC tests, both in -3.35+ 2.36 mm and -1.70+ 0.85 mm size fractions, can be seen in Figure 2.

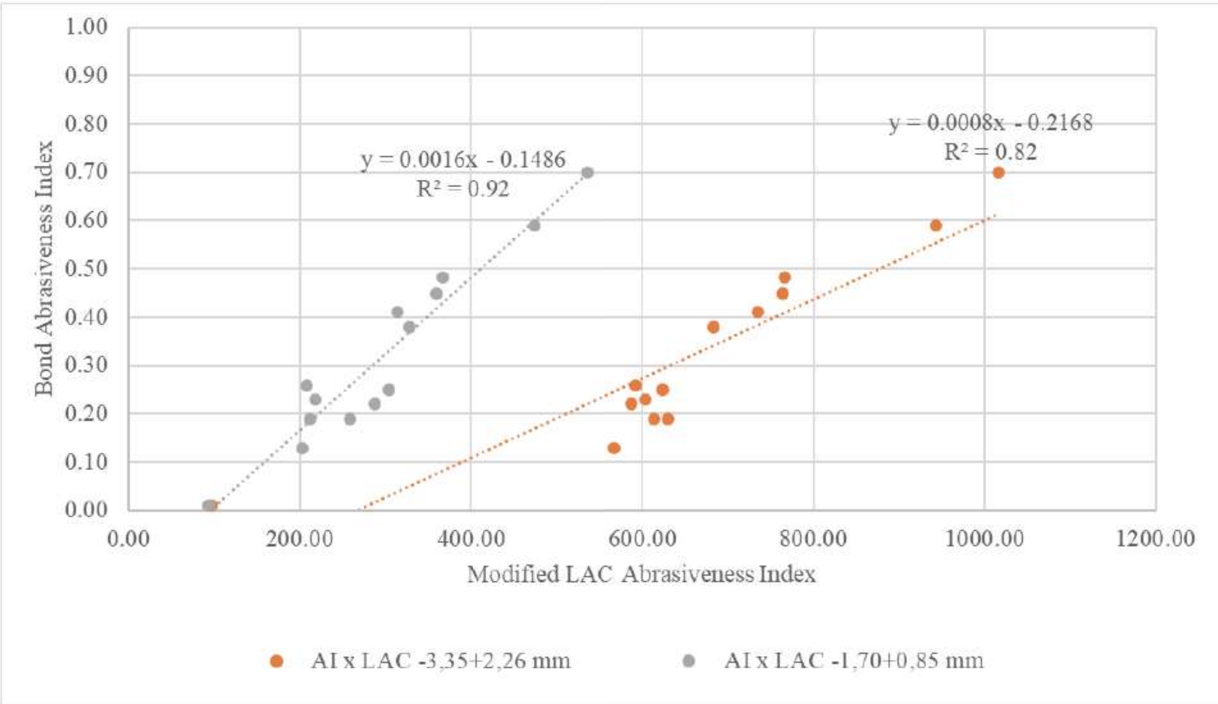

Fig. 2. Correlation between Bond AI and Alternative LAC

There is a clear relationship between the indices determined by the modified LCPC test, both for the size fraction of -3.35+2.36 mm and -1.70+0.85 mm and the Bond Abrasion Index, most commonly used by the mining industry. Considering that in many cases there is no mass or sample in the size range required for the Bond Abrasion test, these modified LCPC test can be a good alternative to determine such abrasion index. Despite these initial good results, more work needs to be done to establish a more robust correlation with the conventional Bond Index in order to confirm the proposed modified LCPC as an alternative for the traditional Bond Abrasion Index.

4. Conclusions

The results have led to the conclusion that there is a clear correlation between the indexes obtained from Bond and LCPC abrasion tests. Based on this correlation, which has been observed and proven in other studies as well, it was possible to develop a modified LCPC test using samples whose particle size is finer than those used in standard tests (from 6.3 to 4.0 mm), e.g., 3.36 to 2.38 mm and 1.68 to 0.81 mm. The derived correlation supports the conclusion that this modified test can be used for such smaller particle sizes to predict the abrasion behavior of ores and rocks. Such results may be used in studies for which coarser particle sizes or masses required for Bond abrasion test are not available, as well as to reduce the testing time when studying large amounts of samples.

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