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Evaluation of grinding media wear-rate by a combined grinding method

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ABSTRACT

It is well-known that lab tests on wear-rate of grinding media cannot precisely represent its industrial performance due to complex grinding conditions. Nevertheless the lab data provides reference to the industrial data. Therefore, a reproducible test method on wear-rate in lab is necessary.

By providing detailed data, this paper challenges the traditional wear-rate testing methods. Two commonly used methods on wear-rate test, self-wear in water and grinding with mineral slurry, are respectively employed. However, obvious fluctuation of wear-rate/time curves indicates neither of the two normal methods is reliable.

This paper introduces a wear-rate testing method on lab scale which combines self-wear in water and grinding with mineral slurry. By this method, some repeatable wear-rate/time curves are displayed after a few hours. The mechanism will be discussed in detail in this paper.

1. Introduction

Wear-rate is one of the most important factors when evaluating the overall performance of grinding media. Therefore, extensive tests on media wear have been carried out by many media suppliers, users and labs (Berthiaux et al., 1996; Blecher et al., 1996a,b; Blickensderfer and Tylczak, 1989; Frances, 2004; Jensen et al., 2010; Radziszewski, 2002). According to some papers (Chenje et al., 2009; Morrow and Sepulveda, 2014) and many feedback from customers of KING'S CERAMICS's, there is a correlation on media wear-rates between lab equipments and industrial mills. Therefore, to get repeatable media wear-rates in lab is very meaningful to predict the media performance in industrial scale. However, two common approaches on media wear test, namely self-wear rate test in water and wear rate test with mineral slurry, are always poor in repeatability in lab. As a grinding media supplier, KING'S CERAMICS has been making efforts in developing a reproducible method in lab to evaluate the wear performance of different ceramic media.

In this paper, we designed a rapid wear-rate testing method on lab scale which took the advantages of the above two mentioned common methods, and comparatively, repeatable results can be drawn from this new method.

2. Experimental

2.1. Test machines

Vertical stirred mill Fig. 1 (left) and rapid pot mill Fig. 1 (right) were used in order to provide robust grinding and impacting forces. Also some detailed parameters of both the two mills are listed in Table 1.

2.2. Test methods

2.2.1. Self-wear in water

1200.0 g grinding media and 400.0 g water were added into the vertical stirred mill to grind for some time. Grinding was conducted at a speed of 900 rpm. The same ceramic media of 600.0 g and water 200.0 g were filled into the rapid pot mill for wear test at 450 rpm.

2.2.2. Grinding with mineral slurry

1200.0 g ceramic media, 400.0 g water and 400.0 g zircon sand (Eucla Zircon Premium Grade with d50 = 92 μm provided by Iluka Resources, 7–8 in Moh's hardness) were added into the vertical stirred mill. Grinding speed was also 900 rpm. 500.0 g identical media, 100.0 g water and 100.0 g zircon sand (same with above) were filled into the rapid pot mill for wear test at 450 rpm.

Both wear-rate test methods are applied in vertical stirred mill and rapid pot mill, with consecutive grinding for 1 h each time. The method was repeated many times to achieve stable wear-rates.

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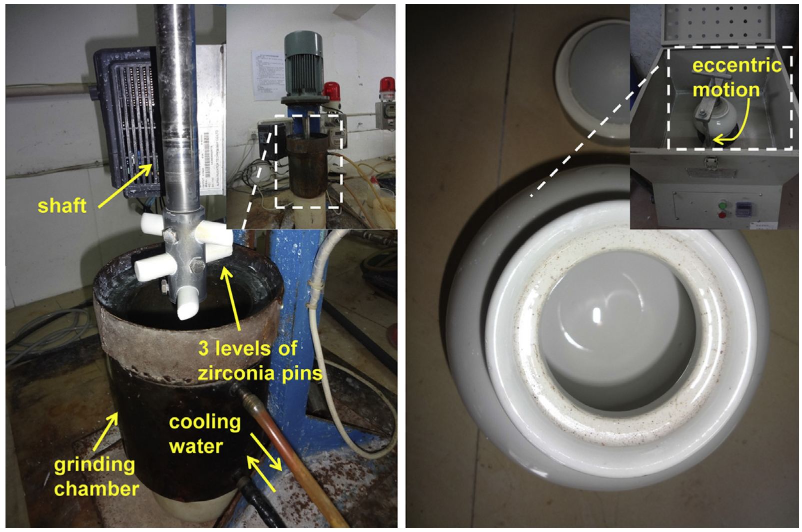

Fig. 1. Vertical stirred mill (left) and rapid pot mill (right).

Table 1
Parameters of vertical stirred mill and rapid pot mill.

Parameters	Vertical stirred mill	Rapid pot mill
Motor power (kw)	0.55	0.45
Grinding chamber volume (l)	1.87	1.0
Impeller length/maximum diameter (mm)	100	150
Operation speed (rpm)	900	450

The hardness of zircon sand is relatively higher among natural minerals, so the wear-rate differences among different grinding media can be maximized.

2.2.3. Combined grinding method

Combined grinding method, which was proceeded in the rapid pot mill, includes two steps: (1) grinding with mineral slurry: the same ceramic media of 500.0 g, water 100.0 g and zircon sand 100.0 g were ground at 450 rpm for 1 h, and then another 2 h in fresh zircon sand slurry after drying the media. (2) Self-wear in water: after grinding with slurry, ceramic media were washed, dried, and then filled into rapid pot mill again (media to water mass ratio is 3:1) to grind for 1 h at 450 rpm, followed by another 2 h grinding in new water under the same condition after drying the media.

2.2.4. Grinding media

Three kinds of ceramic media with different densities of 3.32, 4.05 and 4.23 g/cm^3 were selected from KING'S CERAMICS and the market, which were named as media A, B and C, respectively.

2.2.5. Calculation on wear-rate

The media wear-rate can be calculated by equation "wear-rate = $a/b/t$", where a is the media loss (g) after grinding, b is the initial media charge (kg), and t is the grinding time (h). The unit of wear-rate is g·kg^{-1} h^{-1}.

3. Results and discussion

3.1. Self-wear test

Self-wear is a simple and easy method, so it is widely used. But it cannot simulate the grinding conditions of practical operation. Fig. 2 shows the self-wear curves of different grinding media in water versus time. The lines marked with diamonds (A1 and B1) are the results in rapid pot mill, and those marked with circles (A2 and B2) are in vertical stirred mill for media A and B, only the wear-rate curve of media C in rapid pot mill is examined. For media A, after grinding for 7 h, a relatively stable wear-rate could be obtained. For media B, it almost needs 8 h to observe a stable values. In case of media C, only a rising wave line is received as shown in Fig. 3, which could not tell us at which time point is reliable to evaluate the wear-rate. The results mentioned above seem to indicate that self-wear is not an adaptable method for different grinding media.

3.2. Wear-rate in mineral slurry

Grinding in mineral slurry is usually used as a relatively reasonable method for testing wear-rate.

The wear-rate curves of different ceramic media grinding with mineral slurry can be found in Figs. 4 and 5. However, the curves of media A and C (only in rapid pot mill) are wave lines in wide

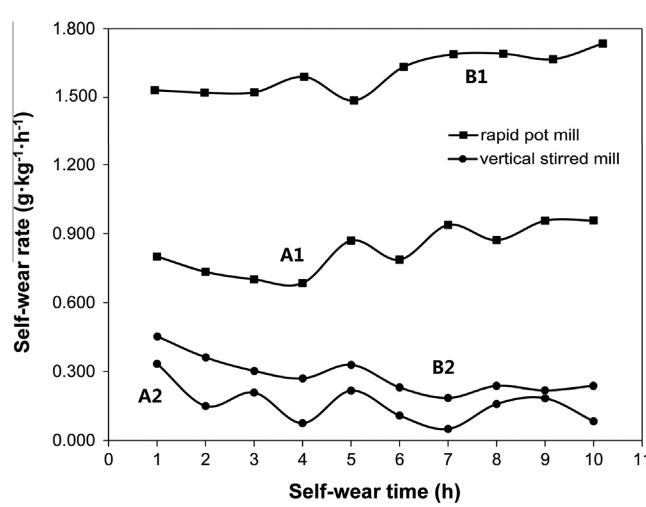

Fig. 2. Self-wear curves of media A and B in vertical stirred mill and rapid pot mill.