Technical note

The effects of grinding media shape on breakage rate

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Abstract

Cylindrical grinding media, which have a slightly spherical shape, called Cylpebs have recently been introduced. Comparative tests have been performed using Cylpebs and balls in a laboratory ball mill under the same conditions of mass and feed. Results show that a faster breakage rate is obtained using Cylpebs as the charge.

Keywords: Comminution; Grinding; Breakage rate grinding media

1. Introduction

The primary function of grinding media is to crush and grind ore particles inside rotating mills, such as ball, rod, and semi-autogenous mills, and sometimes in mechanically stirred mills.

In recent years, grinding charges with unconventional shapes have appeared on the market. One example is the cylindrically shaped media called Cylpebs (Shi, 2004). Cylpebs have greater surface area and higher bulk density than balls of similar mass and size, due to their shape. Cylpebs of the same diameter and length have 50% greater surface area, and 45% greater weight, than balls of the same material. In addition, they have 9% higher bulk density than steel balls, and 12% higher than cast balls.

The objective of this paper is to compare Cylpebs and ball grinding media in terms of grinding kinetics.

2. Background

It has been experimentally confirmed that batch grinding of brittle material in various types of small laboratory mill is defined by first order breakage (Austin et al., 1981):

\[ \log[w_1(t)] = \log[w_1(0)] - S_t / 2.3 \]

where \( w_1(t) \) is the weight fraction of mill hold up that is of size \( 1 \) at time \( t \) (Austin et al., 1981, 1984; Deniz, 2004). \( S_t \) is assumed to be constant with time \( t \), and is determined from the slope of \( w_1(t)/w_1(0) \) versus \( t \) on a semi-log plot. This rule is known as the first order grinding hypothesis.

The formula proposed in several papers for the variation of the specific rate of breakage \( S_i \) with particle size is

\[ S_i = \frac{a_T (x_i/x_0)^\alpha}{[1 + x_i/\mu]^A} A > 0 \]

where \( a_T \) and \( \alpha \) are constant for a given material ground in a particular mill under defined operating conditions, and \( x_0 \) is a reference size, usually 1000 \( \mu m \), \( \mu \) is the particle size at which the denominator is 0.5 and \( A \) is an index of how rapidly the rate of breakage falls away (Austin et al., 1982; Prasher, 1987; Teke et al., 2002).

3. Experimental techniques

3.1. Grinding charge

The grinding media used for the tests were \( 20 \times 20 \) mm diameter Cylpebs and \( 20 \) mm diameter...
balls, made from cast iron. Specific gravities of Cylpebs and balls were 7.35 and 7.69 g/cm$^3$ and their surface areas 18.84 and 12.56 cm$^2$, respectively.

3.2. Test material

Seven different mono sized feed fractions of quartz with a specific gravity of 2.68 g/cm$^3$, containing 99.62% SiO$_2$, were used for all the tests.

3.3. Experimental method

Grinding experiments were carried out in a stainless steel laboratory mill of 30.5 cm length and 30.5 cm diameter, with a smooth lining, rounded corners and operating at 70 rpm. During all the tests, mill feeds were constant, 3000 g being used. 19794.2 g of Cylpebs and 19776.9 g of balls were used separately in the grinding charge.

In order to determine the specific rate of breakage, feed samples were prepared in seven different mono sizes and ground batch wise using Cylpebs and ball grinding charges for selected periods (0.5, 1, 2, 4, 8 min). After each grinding period, the product was discharged and a 375 g of sample was representatively taken by riffling, followed by dry sieving for 15 min on a Rotap.

4. Results and discussion

The first order plots for different feed sizes of quartz ground by balls and Cylpebs are illustrated in Figs. 1 and 2, respectively. The results indicate that grinding of all size fractions can be described by first order grinding kinetics with 0.9197–0.9991 correlation coefficients.

Variations in specific rates of breakage at different feed particle sizes for ball and Cylpebs grinding charges are shown in Fig. 3. The specific rate of breakage increases up to $-1180 + 850 \mu m$ feed size, but above this size fraction breakage rates decrease sharply for both grinding charges, since the particles are too large and strong to be properly nipped and fractured by the Cylpebs and the balls, and have a slow specific rate of breakage.

Parameters of specific rates of breakage $a_T$, $\alpha$, $\mu$, $A$ were obtained by non-linear regression (from Fig. 3 and Eq. (2)), and are 0.73, 1.57, 1.27, 3.65 for ball charge and 0.82, 1.50, 1.28, 3.29 for Cylpebs charge, respectively. As can be seen from Fig. 3, Cylpebs give faster rates of breakage than do balls. This can be attributed to the linear and point contacts of Cylpebs on each other.

5. Conclusions

Cylpebs produced faster breakage rates than ball charges under the same conditions. The differences between the breakage rates are more significant for the coarse fractions than for the fine fractions.

References

Austin, L.G., Shoji, K., Bell, D., 1982. Rate equations for non-linear breakage in mills due to material effects. Powder Technol. 31, 127–133.


