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The shape of product size distributions in stirred mills

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Abstract

This paper presents the results of an extensive laboratory and pilot stirred milling testwork program conducted using different types of mills, fed with different types of materials and operated at different conditions. The results indicate that the slope of the product size distribution (PSD) curve remains relatively unchanged in the coarse product size range but decreases in the fine product range (less than about 20 μm size), regardless of the type of stirred milling technology used for grinding. This work therefore confirms that a narrower product particle size distribution than the feed size can be achieved independent of the type of stirred milling technology used for fine grinding below 20 μm. The change in the PSD width in fine grinding is due to the change in the material breakage properties and a change in the mill operating conditions which affect the breakage process. In the normal operating range of grinding media size, the effect on the PSD shape is not significant.
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Keywords: Fine particle processing; Grinding; Sizing

1. Introduction

Fine grinding is becoming increasingly more important in the minerals processing industry as new ores are predominantly fine grained and refractory. Besides minimizing energy consumption, a narrow size distribution is often desirable in the subsequent mineral separation stages. For the flotation separation the highest recoveries are obtained for the medium size range particles while there is a reduced recovery at both fine and coarse end of the size distribution. It is well established in conventional ball mill grinding that the shape of the product size distribution curve depends primarily on the properties of the material being ground (Klimpel, 1998) and is generally similar (parallel) to the feed size distribution (Bond, 1961). This means that the particle size distribution (PSD) spread remains generally constant.

For fine grinding using stirred milling, a number of studies suggest that the product size distribution (PSD) spread decreases as the product becomes finer. A study carried out using different types of horizontal stirred mills (Karbstein et al., 1996) shows that the width of the particle size distribution, described by the ratio $(x_{90} - x_{10})/x_{50}$, decreases with increasing specific grinding energies (i.e. finer product size) irrespective of the type of mill. However, it is possible to alter the width of the particle size distribution (PSD) by the mode of operation: the circulation, where slurry is continuously circulated between the mill and a tank, the passage, where the mill is fed from a feed tank and the products discharged into a separate tank or by the introduction of a classification stage (Karbstein et al., 1995). Fig. 1 shows that the particle size distribution width reduces sharply with specific grinding energy input for batch operation. It also shows a significant difference in the particle size width between the circulation (Kreisfahrweise) and passage (Passagenfahrweise) modes of operation.

For the same material ground using the same stirred mill design. Nesset et al. (2006) showed that the PSD width will be affected by the grinding media size and to a lesser effect by the grinding media and slurry density. It was also

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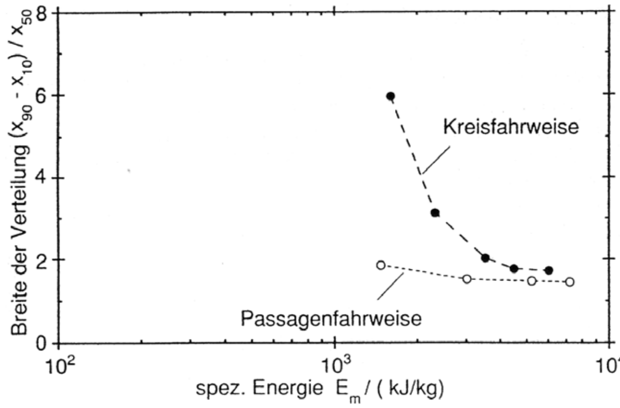

Fig. 1. Product particle size distribution slope change with specific grinding energy input – after Karbstein et al. (1995).

observed that the "the particle size spread was tightest" under the most energy efficient operating conditions for the different stirred milling technologies tested. For product sizes below a P_{80} of 20 μm, the PSD width decreased as the product size became finer.

This paper presents an analysis of the particle size distribution (PSD) obtained from three different laboratory fine grinding stirred mills grinding different materials.

2. Experimental work

The data analysed in this paper was collected from grinding testwork performed using three different types of stirred mills shown in Fig. 2.

Continuous (passagewise mode) grinding tests were carried out in a laboratory and pilot size Tower (1.5 kW) and SAM (8 kW) mills using different size steel balls. Commercially available calcite, with an F80 of approximately 65 μm, quartz (silica sand) with an F80 of approximately 145 μm and 65 μm, were ground. The slurry was pumped into the mill (pass 1) and discharged into the product tank. When the feed tank was emptied out, the slurry from the product tank was returned to the feed tank and the test was continued (pass 2). The process was repeated several times depending on the test conditions. The samples for the product particle size analysis (40 ml) from the mill discharge were taken towards the end of each pass. The summary of the testwork is presented in Tables 1 and 2. For each test several products were collected and sized depending on the number of passes performed.

Grinding tests were also performed using a variable speed (450 rpm max) pin-type laboratory attrition mill, similar to Metso's laboratory Stirred Media Dertitor (SMD®). Batch grinding tests were carried out with zinc concentrates supplied by two different mining operations, both with a 80% passing size of around 40 μm. For each test several product samples were taken for sizing at predetermined grinding times. The tests were performed to assess the effect of changing the media size, media density and stirrer mill speed. A summary of the test conditions is given in Tables 3 and 4.

Power consumption and the grinding product's size distribution were measured in all tests. Malvern laser sizer was used for measuring the size distribution of the grinding products.

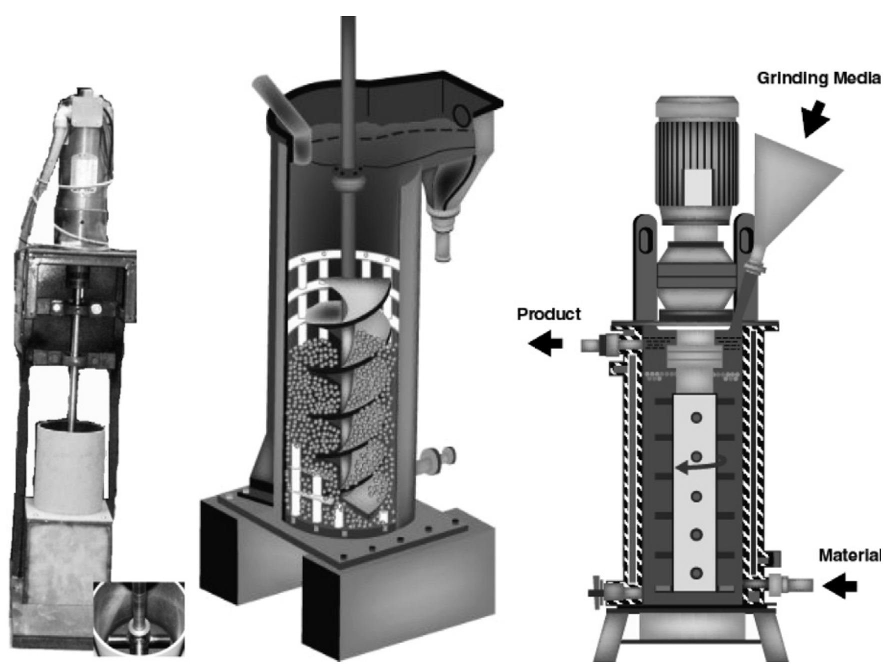

Fig. 2. Mills used in the testwork: laboratory pin attrition mill, pilot Tower mill and Sala Agitated Mill (SAM).

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