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Ultrafine Grinding of Kokaksu Bauxite ore via Stirred Mill and Ball Mill

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The mining industry has a requirement to treat fine (<30 µm) and ultrafine (<10 µm) feed materials, a target difficult or ineffective for traditional milling processes such as conventional tumbling ball milling. The favoured route has been the use of stirred mills. Stirred mills are primarily used for ultrafine grinding applications in the mining industry. In this study, bauxite samples were grinded to ultrafine size (~5 µm) by a laboratory scale stirred mill and its performance was compared with a laboratory scale conventional ball mill. The stirred mill was found to be more efficient (lower grinding time and lower energy consumption) in ultrafine grinding.

Key words: Ball Mill; Bauxite; Micronized Grinding; Stirred Mill

1. Introduction

In many different industries today, such as, plastics, ceramics, cement, metallurgy, paint, food, cosmetics and energy, there is a growing need for materials identified as fine and ultrafine. The situation is almost the same in the mining industry as well. The use of stirred media mills in mineral processing is increasing. In the last 20 years, the discovery of more complex, fine-grained ores containing base and precious metal deposits has necessitated greater degrees of size reduction. Liberation of these metals typically demands grinding to less than 10 µm. Also, in ultra-clean coal production technology, the coal should be grinded below 10 µm [1]. In mineral processing, four grinding "stages" can be identified, based on the size of the grinding product. Traditionally, grinding to 80% passing 75 µm is regarded as "conventional" since many operations grind to that size. Regrinding is considered to produce the particles finer than 75 µm down to 30 µm. Fine grinding is a relatively new area and considers grinding below 30 µm down to around 10 µm. Below 10 µm, the term "very fine or ultrafine grinding" can be used. The energy consumption in ball milling rises sharply for grinding products below 75 µm and below 30 µm grinding using ball mills becomes uneconomical. With the introduction of stirred media mills, fine grinding becomes economical and there are several base metal concentrators today that grind as low as 10 µm [2-5].

The specific energy consumption for grinding is less than that of ball mills due to the high media volumetric loading in stirred mills. Unlike ball mills, where grinding occurs from both impact and attrition grinding, in stirred media mills the particles suffer almost entirely attrition breakage between the beads. In stirred mills there are no free-falling possibilities for grinding media, meaning that impact action does not occur. The ball size is small, typically 1 to 6 mm which means a large amount of contacts and high grinding efficiency especially in the finest range, where ball mills are not effective or cannot reach P80 10 to 40 µm. Stirred mills can be classified into a number of different subcategories generally defined by the speed, geometry, and orientation of the media agitator or stirrer. The most commonly used stirred mills in mining and minerals processing industry are the Vertimill, The ANI-Metprotech SVM mills, Sala Agitated Mill, HIGMill, Tower Mill, Stirred Media Detritor (SMD) and ISAMill [6-13].

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In this study, the performances of stirred and ball mills for fine and ultrafine grinding of bauxite ore were investigated.

2. Materials and Methods

2.1 Stirred Mill and Ball Mill

Laboratory scale stirred mill uses a grinding pot filled with small balls whereby grinding takes place by attrition between the balls. The stirring effect is caused by rotating pins mounted on a hexagon shaped shaft (Figure 1). The hexagon shaped stirring probe (rotor), vertically going through the mill body comprises sixteen equally located 9 × 6 × 34 mm cylinder stirring pins. The mill motor is operated at 2.2 kW and the maximum rotation speed of the stirrer is 1500 rpm.

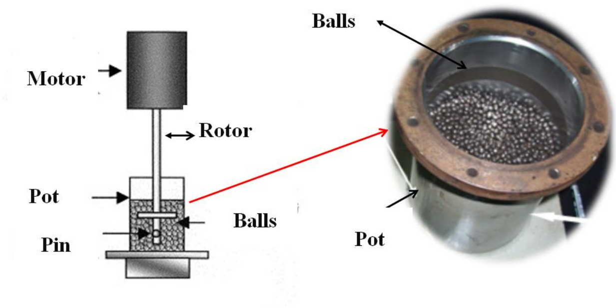

Figure 1. The stirred mill and grinding balls

The laboratory scale ball mill dimensions were 30.5 x 30.5 cm and its rotation speed was 70 rpm. For the grinding media, steel balls in various numbers and of different sizes (43 x 3.68 cm, 67 x 2.97 cm, 10 x 2.54 cm, 71 x 1.80 cm and 94 x 1.15 cm) were put into the mill. The bauxite feeding amount was 100% to cover the gaps among the balls.

Figure 2. Laboratory scale ball mill

2.2. Characterization of Bauxite Sample

The bauxite sample used in a laboratory scale stirred mill and ball mill grinding tests were taken from Zonguldak Kokaksu Bauxite Mine in Turkey. Chemical composition of the bauxite sample is given in Table 1. The sample was crushed by a cone crusher below 3.35 mm and fed into both laboratory scale stirred and ball mills. d_{50} size of the fed sample is 780 microns.

Table 1. Chemical composition of the bauxite sample

Components	Percentage, %
Al_2O_3	53.20
Fe_2O_3	21.15
SiO_2	8.20
TiO_2	1.90
Others	1.50
Loss of Ignition	14.05

3. Results and Discussions

The energy consumption of stirred mill and ball mills versus the change of the median (d_{50}) sizes of the grinded products are shown in Fig. 3. When the energy consumption is 11.10 kWh/t in the Ball mill, the median size of the grinded product is 345 µm; in the stirred mill, it is 430 µm. Similarly, for a 21.4 kWh/t energy consumption, the median size of the product is 200 µm in the ball mill; and, 292 µm in stirred mill. Therefore, the Bond mill is more advantageous than the stirred mill regarding energy consumption. However, when the energy consumption exceeds 33.6 kWh/t (crossing point on Fig. 3), the stirred mill becomes more advantageous. For example, when the energy consumption is 81.3 kWh/t in the stirred mill, the median size of the product is 34 µm; and, 101 µm in the Bond mill. As a result, when the energy consumption is 33.6 kWh/t, the median size of products for both mills is 140 µm. Moreover, in grindings below this size, the stirred mill consumes less energy; whereas, above this size, the ball mill consumes less energy.

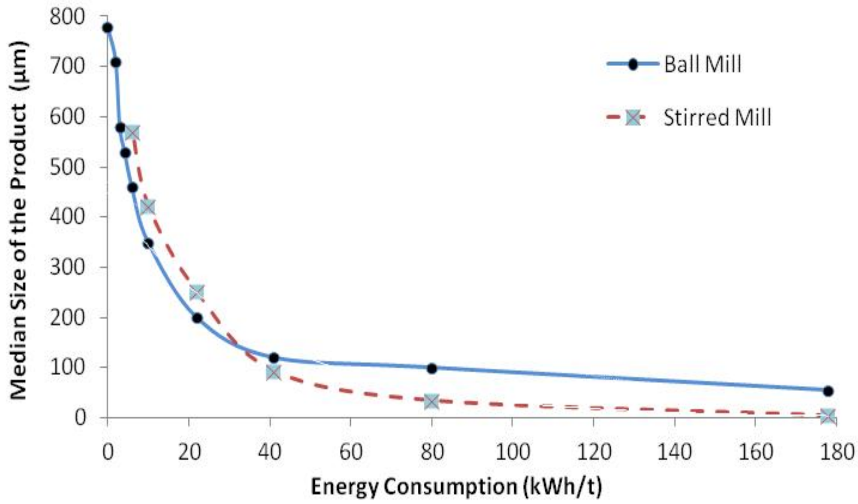

Figure 3. Energy consumption values of Ball and stirred mills vs. the median sizes of the grinded products.

4. Conclusions

Stirred mill is more advantageous in micronized and nano grinding. On the other hand, ball mill provides high performance in the coarse (>100 µm) grinding process. Stirred mills should be preferred, especially if finer grinding than 140 µm. In other words, energy savings in micronized grinding can be achieved by the use of the stirred mill. Stirred media mill decreased bauxite d50 size from 780 to 5 µm in 3 minutes. But the conventional ball mill has reduced to 455 µm at the end of the same grinding period. In addition, the energy consumed by the ball mill for similar fineness (5000 nm) was ~300 kWh/t, while the stirred ball mill consumes ~174 kWh/t energy. As a result, the stirred mill consumes less energy, less time and provides finer products in ultra and nano fine grinding operations.

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